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NEW ULTRASONIC STANDARD DESIGN CRITERIA

W. H. Sproat
Lockheed-Georgia Company
Marietta, Georgia 30063

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Materials Laboratory
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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K. D. Shimmin

K. D. SHIMMIN
Project Engineer

FOR THE COMMANDER

D. M. FORNEY, Jr., Chief
Nondestructive Evaluation Branch
Metals and Ceramics Division
Materials Laboratory

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The purpose of this effort was (1) to identify, on solid theoretical grounds, an alternative approach, to the standardization and calibration of ultrasonic nondestructive evaluation (NDE) systems, which would overcome the limitations of the commonly employed flat bottom hole standards, and (2) to design and fabricate a laboratory prototype device to demonstrate the alternative approach to NDI standards. After establishment of the performance criteria to be met by the alternative standard, an approach based on a software programmable electronic standard simulator was selected

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for the design and construction of the prototype demonstration device. The resulting device has the capability of assisting the user in: (1) equipment checkout and calibration, (2) set-up on reference standards and (3) diagnosis of equipment malfunctions. The ultrasonic standard simulator may be used in either an automatic mode, to perform pre-programmed tests or in a manual mode to evaluate and/or calibrate either the ultrasonic electronic equipment on the entire inspection system including both electronics and transducers.

FOREWORD

This Final Technical Report covers the work performed under contract No. F33615-79-C-5022, from September 1979 to September 1980. The contract entitled "New Ultrasonic Standard Design Criteria", was conducted by the Lockheed-Georgia Company, Marietta, Georgia within the Electronics Laboratory and the Technical Services (NDE) Department. It was administered for the Air Force by Messrs. J. R. Petru and K. Shimmin of AFWAL/MLLP. The principal investigator and engineers on the contract were Messrs. W. H. Sproat, H. E. Fritz and L. Walthour.

The work performed on this contract was directed toward the design and fabrication of a prototype device which is an alternative to flat bottomed hole standards for ultrasonic Nondestructive Evaluation applications. The device also has the flexibility to perform equipment diagnostics and reference standard functions. The reader is cautioned however, not to view the product of this effort as the final prototype design or the answer to the full spectrum of NDE standard needs. It is a first step in concept demonstration of a software programmable electronic device for ultrasonic NDE systems checkout, adjustment and reference.

CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	PROGRAM OBJECTIVE & SCOPE	2
	2.1 Performance Criteria	3
	2.2 Concept Formation	5
	2.3 Program Scope	5
3.0	PHASE I - THEORY & DESIGN	6
	3.1 Prior Work of a Similar Nature	7
	3.2 Design Criteria	7
4.0	PHASE II DEVELOPMENT	10
	4.1 Direct Connect Mode	10
	4.2 Face-to-Face Mode	14
	4.3 Analog Circuit Functions	14
	4.4 Digital Circuit Functions	21
	4.5 Transducer Design	21
	REFERENCES	37
	APPENDIX: ULTRASONIC STANDARD SIMULATOR OPERATION	38
	A.1 Simulator Description	38
	A.2 Checkout & Calibration, Direct Connection to the Instrument	47
	A.3 Checkout & Calibration with Transducer	51

LIST OF ILLUSTRATIONS

Figure		Page
4-1	Direct Connect Mode of Standard Operation	11
4-2	Face-to-Face Mode of Standard Operation	11
4-3	Microprocessor Control of Analog Circuits in the Ultrasonic Standard Simulator	12
4-4	Direct Connect Mode Applied to Ultrasonic Instrument Checkout	13
4-5	Face-to-Face Transducer Mode Applied to Total Ultrasonic System Set-up	15
4-6	Analog Circuit Design for Direct Connect Mode of Operation	17
4-7	Analog Circuit Design for Face-to-Face Mode of Operation	19
4-8	Digital Control Bus - System Memory and Serial Input/Output Interface Design (sheet 1 of 2)	23
4-9	Digital Control Bus - System Memory and Serial Input/Output Interface Design (sheet 2 of 2)	25
4-10	Front Panel Control Interface Circuit Design	27
4-11	Transducers, 0 Degree and 45 Degree, Dedicated to 5 MHz Face-to-Face Operation	29
4-12	Impedance Locus for the Left Half of the 0 Degree Split Element Transducer (sheet 1 of 2)	31
4-12	Impedance Locus for the Right Half of the 0 Degree Split Element Transducer (sheet 2 of 2)	32
4-13	Impedance Locus for the Left Half of the 45 Degree Split Element Transducer (sheet 1 of 2)	33
4-13	Impedance Locus for the Right Half of the 45 Degree Split Element Transducer (sheet 2 of 2)	34
4-14	R. F.Waveform Analysis for the 0 Degree Transducer, Dual Element Excitation	35
4-15	R. F. Waveform Analysis for the 45 Degree Transducer, Dual Element Excitation	36

LIST OF ILLUSTRATIONS - Cont'd.

Figure		Page
A-1	Ultrasonic Standard Simulator Front Panel Controls, Display and Connections	39
A-2	Keypad Symbols for Ultrasonic Standard Simulator Function Controls	41
A-3	Automatic Test Mode (Direct Connect) 1.0 and 1.2 Responses by an Ultrasonic Instrument. Pulse Widths are 1 and 4 Microseconds.	42
A-4	Automatic Test Mode (Direct Connect) 2.0 and 2.1 Responses by an Ultrasonic Instrument. Pulse Widths are 2 and 4 Microseconds.	43
A-5	Automatic Test Mode (Direct Connect) 3.0 and 3.2 Responses by an Ultrasonic Instrument. Functions are the same as 1.0 and 1.2 except for Slope.	45
A-6	Automatic Test Mode (Face-to-Face) 5.0 and 5.1 Responses by an Ultrasonic Instrument. The Two Adjacent Pulses Simulate Near Surface Resolution. The Second Photo Shows Simulation of a Mid-Position Reflector in the Sound Path.	46

LIST OF TABLES

Table		Page
A-1	Pulse Input Settings for Commercial Instruments	48

1.0 INTRODUCTION

Ultrasonic non-destructive evaluation (NDE) standards are used as devices to compare and adjust ultrasonic system response to known characteristics such as wave reflection and scattering from specific discontinuities at given distances from the wave source. One of the most common standard configurations is a metallic test block with a flat bottomed hole which represents a disk-like scatterer or reflector. Birnbaum and Eitzen [(1)] have summarized the intended purpose of these devices as the following:

- to check overall equipment performance,
- to check transducer performance,
- to determine the inspection sensitivity level and its limitation on resolution,
- to adjust the instrument settings for range,
- to set accept-reject criteria,
- to make system performance evaluation possible in the sense that test results are reproducible from day to day, article to article, location to location, instrument to instrument and laboratory to laboratory.
- to simulate to some degree, the geometry of the anticipated defect,
- to simulate to some degree, the geometry of the part under inspection.

The first six purposes are common to "calibration" standards. The term "calibration" is used loosely here, in that a true calibration involves comparisons with and adjustments to fundamental values such as sound pressure level or intensity. The two remaining purposes which involve simulation are typical of reference standards.

The generally accepted design and application of test blocks in the United States is specified by the American Society for Testing and Materials (ASTM) Recommended Practice E127. The above authors have commented on the advantages and disadvantages of these blocks in the following way:

"Test blocks have the following advantages. They check a complete system: instrument, search unit, cable, connections and couplant for sensitivity and noise level; allow a meaningful resolution check under actual operating conditions with a variety of search units and they establish initial set-up conditions. They can provide direct comparison of echo amplitude for determining material acceptability on a customer-to-vendor basis. Test blocks have a number of disadvantages: they may be difficult to reproduce precisely; they do not easily allow a separation of search unit and instrument characteristics; it may be costly and time consuming to perform standardization and calibration using test blocks; even with the same block, reproducibility may be difficult depending on operator capability; and, finally, there is a certain lack of versatility."

Air Force maintenance needs add to the complexity of the problems associated with test blocks when in-service applications are considered. Non-destructive inspection tasks in maintenance of aircraft require a myriad of reference standards which simulate structure and engine components. It is both cumbersome and expensive to maintain a large inventory of reference standards. Additionally, many applications require shear wave NDI which cannot use flat-bottomed holes in conventional test blocks as standards.

Solutions to some of the problems with standards have been approached through improvements to ASTM-type reference blocks and the development of new approaches based on the theoretical scattering behavior of ultrasonic waves which impinge on discontinuities embedded in solids. Additional work however, remains in tailoring ultrasonic NDE standards to numerous Air Force applications.

2.0 PROGRAM OBJECTIVE AND SCOPE

The overall objective of this program is to design ultrasonic NDE standards which conveniently provide calibration and reference features to determine equipment performance capabilities and to aid in the proper setting of equipment operating parameters. The optimum standards concept must provide unambiguous and uniform response, be accurately producible and applicable to manufacturing and maintenance environments.

2.1 Performance Criteria

The following list of criteria from reference (1) supplements the above statement of performance objectives and specifies those features which are desirable and essential to effective standards design.

a. Functional adequacy. Will the standards reliably and adequately accomplish their intended use?

b. Reproducibility of test results. Can the test results be reproduced not only within a given organization but also among different laboratories?

c. Ease of duplication. Can the standards be fabricated at different laboratories and at a reasonable cost?

d. Ultimate cost of standardization. How much will it cost the users to implement an adequate standardization program? Will such a program be cost effective?

e. Versatility in providing simulated situations. How many reference standards are needed to carry out calibration of various instruments for different test objects?

f. Correlation with real defects. Can real defects be quantitatively compared with the reference standards?

g. Availability of independent examinations. Are there independent techniques (such as radiographic techniques) to verify the standards?

h. Compatibility with existing standards. Is the proposed standard compatible with or traceable to existing standards?

i. Availability of a theoretical basis. Is there a theoretical model to establish the standards and to verify and extrapolate the results?

j. Ease of automation. How readily can the standard system be automated to reduce reliance on operator performance?

k. Ease of implementation. How easy is it for an operator to use the standard?

1. Ease of modification to satisfy future needs. How readily can the standard be adapted to meet future requirements?

The selection of an optimum design concept for the Air Force would satisfy all of these criteria and would be especially suited to the environmentally harsh and demanding use in a field or depot location.

2.1.1 Practical Use of Standards

Experience in measuring nondestructive inspection (NDI) capabilities through the extensive on-site data acquisition at Air Force field and depot facilities [(2)] has influenced concept formation in this program. The observation of technician performance in ultrasonic equipment set-up or calibration has emphasized the in-service perspectives in defining functional adequacy of hardware/software design. These observations have shown a great deal of variability in task assignments from day-to-day confront the NDI technician; coupled with numerous equipment makes, models and states of operation which are likely to exist in the same shop. These factors of complexity are compounded by the limited experience for many personnel because of high turnover rates in the military staffing of NDI shops. Field needs for standards therefore, are characterized by adaptability to a broad range of NDI tasks which are performed by relatively inexperienced personnel.

Ultrasonic equipment, procedures and operation are also inherently more complex than most others in NDI. There are a number of control settings which can be interactive or interdependent in the flaw detection process. Technicians who have undergone both formal and on-the-job training over a 6 month to 2 year period for example, are still unsure of their proficiency in operation. The setting of appropriate operating parameters specified by written procedures and physically observed by trials on a reference standard, are subject to much error and uncertainty.

Additionally, flat bottom hole standards are rarely, if ever used in the field shops. The in-service needs for ultrasonic standards are:

a. a clearly defined purpose or function,

b. compatibility with relatively unskilled operator use,

c. capability to generate or produce clear and unambiguous responses on equipment displays,

d. convenient selection among numbers of specific standard types,

e. flexibility to changing needs and numerous configurations,

f. portability to inspection site applications,

g. positive identification of the selected standard,

h. repeatable performance with traceability to master standards,

i. low unit cost

The needs and requirements for ultrasonic standards in a manufacturing environment are very similar to those stated for in-service applications. The one difference can be in the area of personnel experience and skill, where manufacturing concerns do not suffer the high turnover rates, exhibited in field NDI shops. In another application, the Air Force depot NDI situation falls midway between the field and manufacturing environment settings. In all cases if the above needs are met, the utility and effectiveness of the standard(s) will enhance the ultrasonic NDE process.

2.2 Concept Formation

The combination of performance criteria and user needs, along with the advent of low-cost microprocessors and integrated circuits, led to a consideration of an electronic device to simulate ultrasonic standards. Programmable features would provide for automatic operation to allow relatively unskilled personnel to perform detailed set-ups and ultrasonic equipment parameter adjustments. Such a device would also allow for flexibility to change and addition or deletion of standards by software programming at low-cost compared to physical standards.

2.3 Program Scope

This has been an eleven month program consisting of two phases: Phase I - Theory and Design and Phase II - Development, Evaluation and Verification.

Phase I was dedicated to the selection of an optimum standards concept and the development of design information necessary to produce a working model. Phase II involved the detailed design and assembly of the working model, along with tests and verification of its performance in an in-service environment.

The standards concept which was selected operates electronically from internally programmed controls. This approach resulted in the application of most of the program resources to hardware and software development. The primary outcome of this effort is therefore an operational prototype of an electronically controlled ultrasonic standard with microprocessor programming flexibility. An operator's manual, which is written and formatted with Air Force field and depot NDI personnel needs in mind, has also been developed to accompany the device. This document is attached as an Appendix to the final report.

3.0 PHASE I - THEORY AND DESIGN

The philosophy of design in this effort was to select an active device concept with inherent flexibility rather than to obtain the desired results from a mass or group of passive objects with built-in discontinuities. Additionally, the criterion of practicality in application to manufacturing, depot maintenance and field operations has required a consideration of human factors. The device must gain acceptance by ultrasonic NDE practitioners and fulfill the needs to provide convenient, unambiguous and reliable calibration and reference functions. In effect, the improved standard function parallels that of automatic test equipment, with special emphasis on ultrasonics. A microprocessor controlled group of typical calibration/reference functions have been made available in a single device. It also provides readout potential for interactions with the user through a front panel alphanumeric display. In its present state, the device is a working tool for concept development and expansion into more extensive treatment of standard needs.

3.1 Prior Work of a Similar Nature

Two devices which have been developed perform functions similar to those of the NDE standard simulator. One of these, the Lynn-O-Check, was applied by General Dynamics, Fort Worth, to instrument gain and linearity tests. A report on its performance was presented by D. B. Cosgrove [3] at the 26th National Conference of the American Society for Nondestructive Testing in 1966. This device generated a train of 38 electrical impulses, with the option of selecting a linear increase in amplitude with time or constant amplitude groups. The increasing pulse group was used to evaluate sweep and gain linearity and the constant amplitude group was applied to reference gain settings. The intent of this device was to perform convenient evaluations of equipment performance in a production environment.

A second device, the Electronic Test Block (ETB), was developed by the Naval Research Laboratory for evaluating tolerance degradation of ultrasonic inspection systems. A report by Chaskelis [4] describes its performance in trial evaluations. It operates as a transponder with its own transducer "face-to-face" with the ultrasonic equipment transducer. The ETB operates in two modes; amplitude linearity and resolution test. It triggers on an incoming pulse and responds with two return pulses. In the amplitude linearity mode, the return pulses are emitted in fixed synchronism with the second pulse, at half that of the first. This ratio is maintained over a 40 dB range to determine amplifier/transducer linearity within widely separated limits. For the sweep resolution test mode, each pulse position is independently controlled for evaluating the separation of contiguous signals. The ETB has been commercially built by Electro-Physics Laboratories, Inc. and is currently used in Navy contract work.

3.2 Design Criteria

The first consideration given to ultrasonic standard needs for the Air Force was influenced by experience gained in evaluating nondestructive inspection (NDI) reliability at field and depot locations. The maintenance environment at these

locations imposes widely varying demands on equipment performance and the application of technician skills. A key element in the performance of effective NDI is technician proficiency and wide variations in performance capabilities were evidenced by the Reliability of Nondestructive Inspection [5] program, as discussed in a workshop on that topic for the Air Force Logistics Command. Ultrasonic methods were especially vulnerable to misunderstanding of detailed inspection procedures, the chance of error in the relatively complex adjustment of equipment operating parameters and the misinterpretations of the system response during the inspection task. The message this reliability observation has given to the technical community is that widely varying types of inspection tasks, coupled with the inherent complexity of equipment, makes effective ultrasonic NDI difficult to achieve in a maintenance environment.

The predominant type of ultrasonic standard used in field and depot maintenance is a simulation of structure or component containing an artificial flaw. The NDI technician follows detailed technical order procedures which contain both narrative and illustrative directions for set-up on these standards. If the aircraft is structurally complex (both airframe and powerplant) and there are numerous points of inspection, the quantity of procedures and standards will be large. The investment in time and materials necessary to effect ultrasonic NDI under these circumstances is significant. Complications from high turnover rates and the training burden with new personnel add to the difficulties inherent to the NDI of complex aircraft systems. If the large quantities of reference standards could be reduced and assistance in equipment set-ups could be semi-automated for technicians who still require additional training, then more efficient ultrasonic NDI could be performed.

The two predominant criteria for standards design with field and depot maintenance needs in mind are to:

1. Provide efficient means to establish large numbers of reference standard functions.
2. Reduce the reliance on operator skill and experience in equipment set-up.

The manufacturing environment is next in the spectrum of ultrasonic NDE applications. Airframe and power plant production requires quality assurance and inspection functions to monitor the integrity of materials processes, components and assemblies. Ultrasonic methods applied in the manufacturing environment must be stable and predictable barometers of product condition with regard to specified limits. There is a need, therefore, to ensure that ultrasonic equipment is performing its intended function within tolerance limits and that performance is quantitatively referenced to specific physical parameters.

The human factors and technician skill levels in the manufacturing environment do not enter the picture nearly as much as they did in the maintenance environment. The work force is more stable, the tasks more routine and the procedures are fewer in number. Automation also comes into play with its attendant controls and repeatable operations. Here, the emphasis on standards needs center around precision, traceability to discontinuity dimensions and accuracy in measurement.*

The predominant criteria for standards design applied to manufacturing needs are to:

3. Maintain traceability on levels of response to given discontinuity dimensions.
4. Provide means to determine both accuracy (systematic error measurement) and precision (random error measurement) of the ultrasonic NDE system.

The laboratory setting is the remaining environment for standards considerations. Research laboratory functions give rise to needs which are nearly identical with those of manufacturing. Applications laboratories which develop procedures

*(Often times, these primary objectives for standards in manufacturing are thought to apply with the same emphasis in maintenance. However, this is not generally the case. Maintenance NDI is charged with the primary responsibility of detecting flaws, not measuring them.)

on the other hand, are routinely working with reference standards. The best standards for laboratory studies should therefore be versatile devices which are applicable to emerging concepts and new developments. The criteria for laboratory standards are to:

5. Fulfill accuracy and precision evaluating functions.
6. Provide versatility in simulating actual flaws.

In effect, the primary criteria for labroatory standards are combinations of those stated for maintenance and manufacturing needs. The above maintenance, manufacturing and laboratory criteria are also elements of the list of features described in Section 2.

4.0 PHASE II DEVELOPMENT

The design criteria were applied to formulate an electronic device concept which is presented in block diagrams in Figure 4-1 through 4-3. One basic mode of operation is shown in Figure 4-1. A direct connect mode electrically couples the standard simulator to the ultrasonic instrument to test and adjust its functions without transducer influences. Once the instrument has been functionally tested or set-up, the total system with the transducer Figure 4-2, is checked with a face-to-face coupling to the ultrasonic standard transducer. The following sections provide details of the developed circuits which perform these functions through microprocessor control as shown in Figure 4-3.

4.1 Direct Connect Mode

This operation shown in Figure 4-4 provides for instrument gain and time base (sweep) linearity checks by triggering on the instrument pulse output and returning a pulse train of five equispaced elements. The amplitudes of the five returns are stepped in increments of 0.6 dB with 32 microseconds between pulses. The mid (third) pulse amplitude is equivalent to the return from a number 5 flat bottomed hole at 4.4cm in 7075-T651 aluminum. The sweep duration places the last pulse at a position equivalent to 10cm distance in the block. This pre-set operation provides for both horizontal and vertical instrument linearity checks.

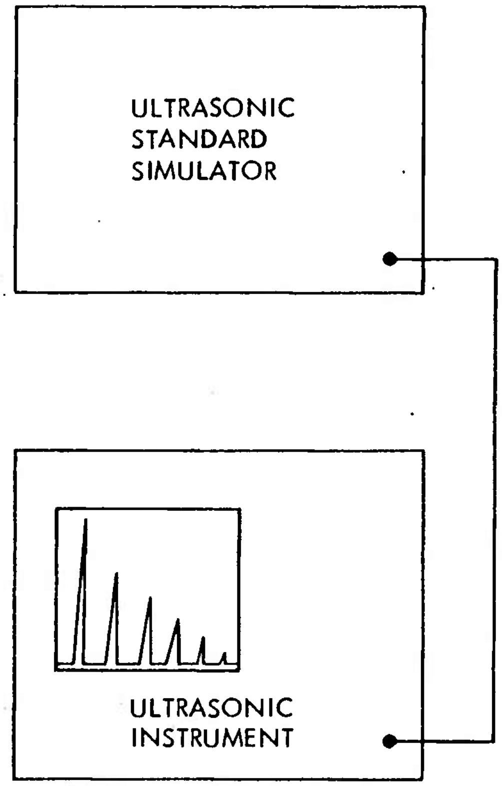


Figure 4-1. Direct Connect Mode of Standard Operation

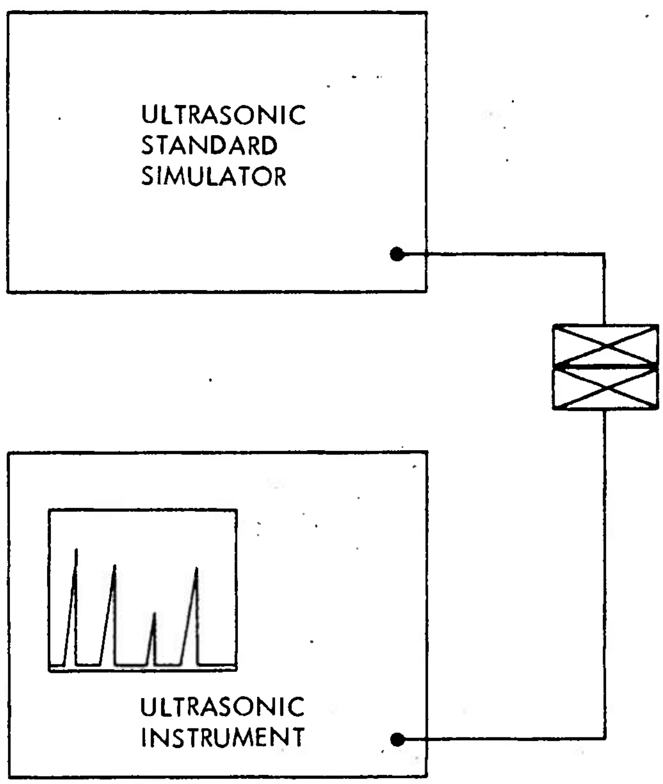


Figure 4-2. Face-To-Face Mode of Standard Operation

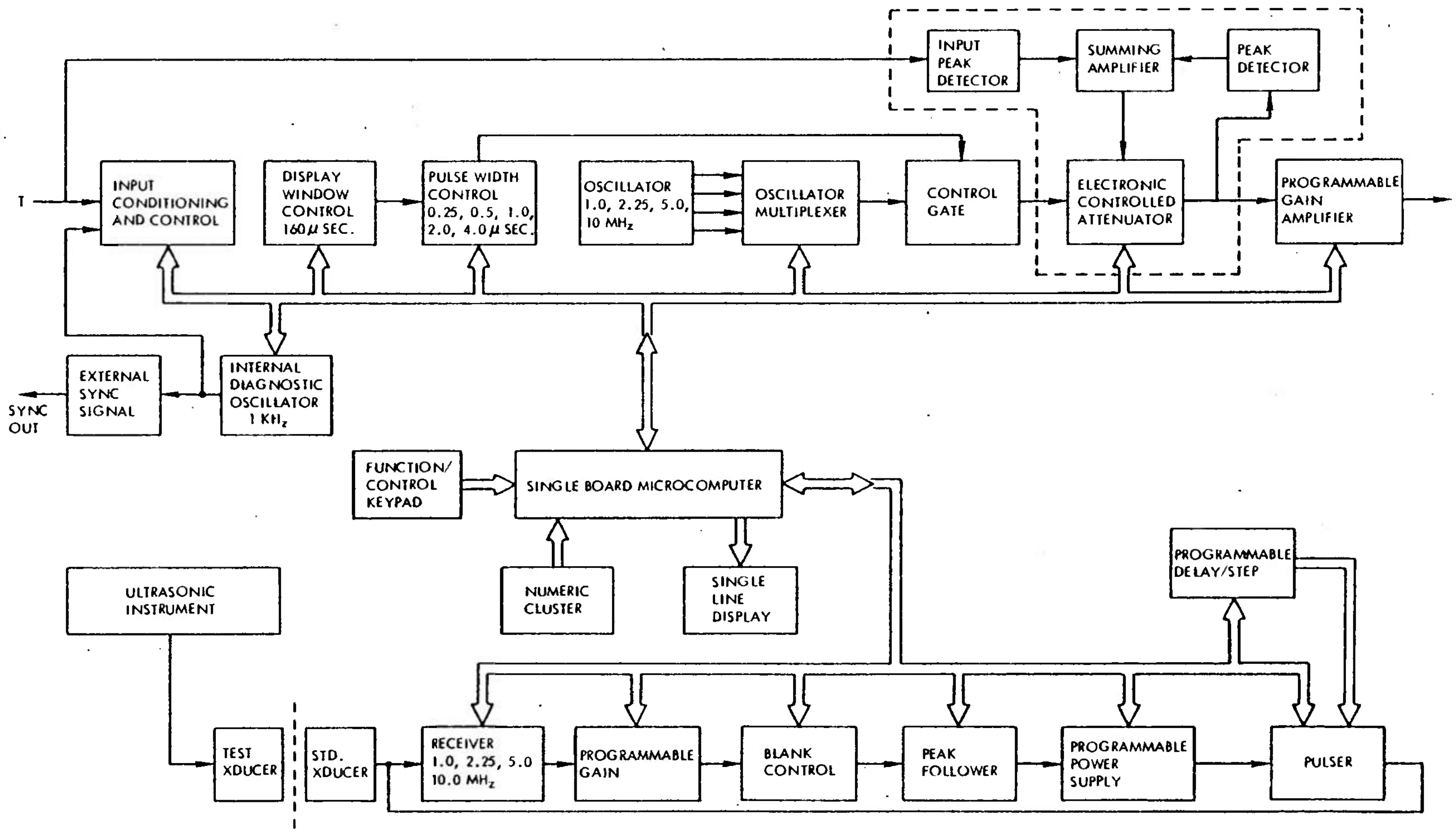


Figure 4-3. Microprocessor Control of Analog Circuits in the Ultrasonic Standard Simulator.

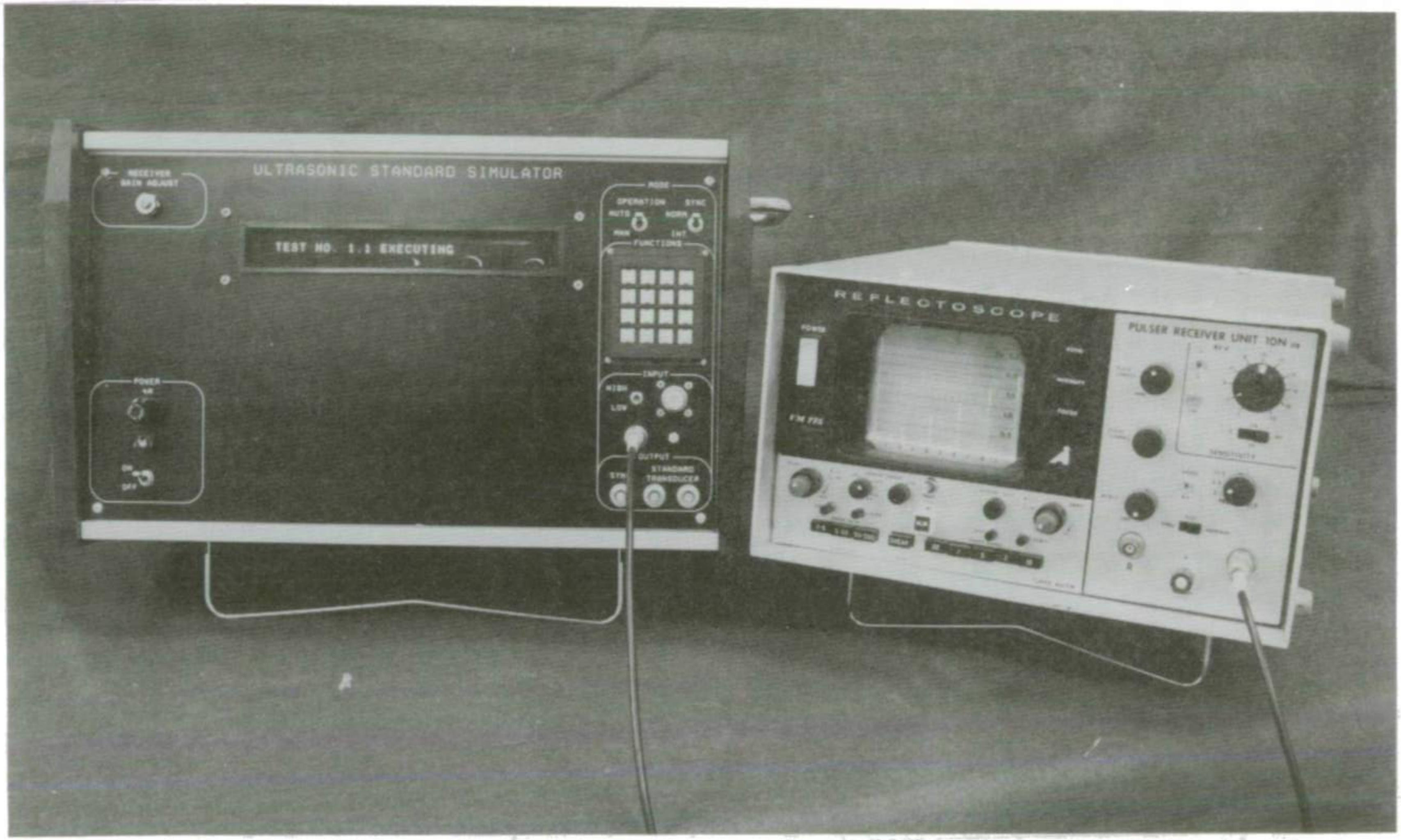


Figure 4-4. Direct Connect Mode Applied to Ultrasonic Instrument Checkout.

4.2 Face-to-Face Mode

Operating in this mode, as shown in Figure 4-5 is software programmable and simulation of any number of standards is possible. The transducer of the ultrasonic NDE system is positioned on the center of the transducer provided with the standard simulator. Ultrasonic pulses are sensed and return pulses, proportioned to the input, are transponded with program selected time and amplitude combinations. Pulses which simulate front and back surface echoes common to longitudinal wave operation, can be established. Intervening pulses of specific amplitude and time values can be positioned between the "front" and "back surface" indications. Similarly, multiple pulses, with prescribed amplitude and time features can be programmed to simulate responses to shear wave NDE configurations. In an equipment checking routine, time base resolution is examined by controlled positioning of two pulses adjacent to each other within shorter and shorter time intervals. Limits in time (distance) resolution are determined where discreet signals remain observable.

4.3 Analog Circuit Functions

The analog circuit design is schematically presented in Figures 4-6 and 4-7. Circuit functions of the schematics in Figure 4-6 are dedicated to the direct connect mode of operation. Four oscillators operating at 1.00, 2.25, 5.00 and 10.0 MHz frequencies provide signals at the selected frequency of operation. Time information is provided by a master clock which controls a programmed attenuator and a retriggerable multivibrator which generates 30 microsecond gates. The 30 microsecond intervals are produced in a series of five, to provide equispaced gated oscillator outputs. A five step programmable attenuator controls the amplitudes of the gated signals in either a ramp or constant level mode. A peak detector and voltage comparator is also included to measure the pulse amplitude of the ultrasonic equipment. The remaining circuit elements in Figure 4-6 are dedicated to switching and control interfaces.

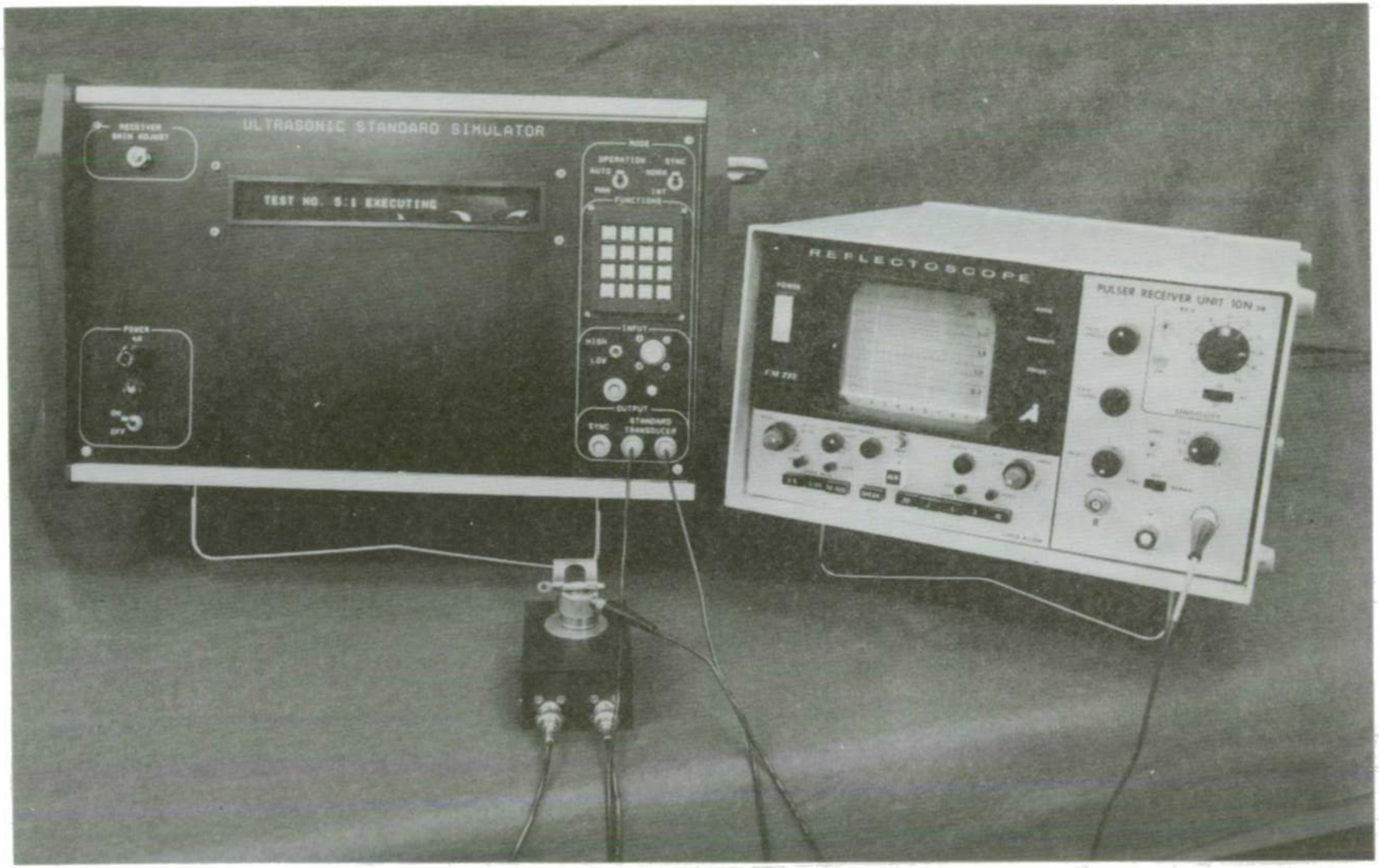


Figure 4-5. Face-to-Face Transducer Mode Applied to Total Ultrasonic System Set-up.

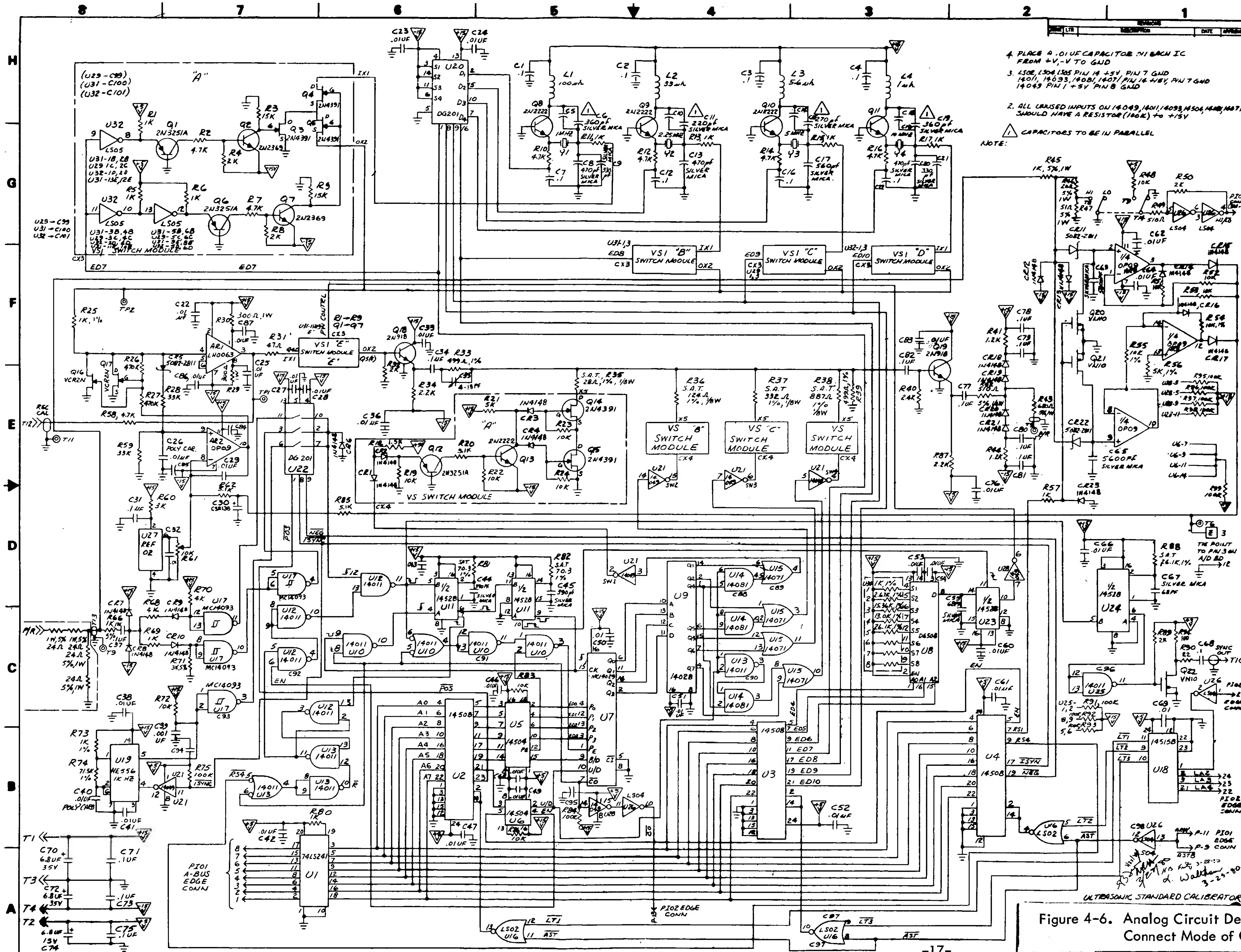
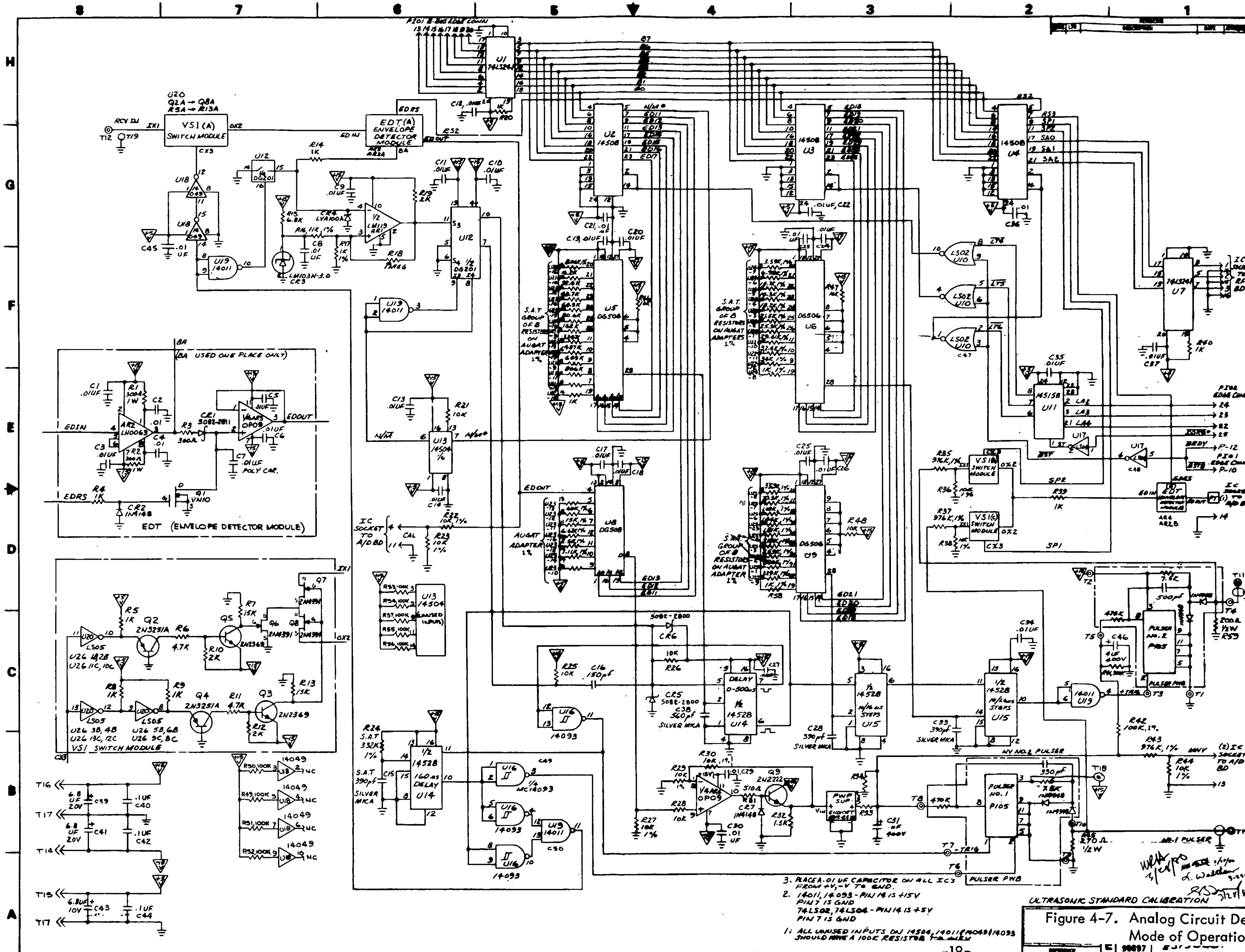


Figure 4-6. Analog Circuit Design for Direct Connect Mode of Operation.



3. PLACE A .01 UF CAPACITOR ON ALL IC'S FROM +V, -V TO GND.
2. 14011, 14093 - PIN 14 IS +15V PIN 7 IS GND
74LS02, 74LS04 - PIN 14 IS +5V PIN 7 IS GND
1: ALL UNUSED INPUTS ON 14504, 14011, 14049, 14093 SHOULD HAVE A 100K RESISTOR TO GND

NOTE:

ULTRASONIC STANDARD CALIBRATION

Figure 4-7. Analog Circuit Design for Face-to-Face Mode of Operation.

The analog circuits in Figure 4-7 are designed for the transducer face-to-face operation. A receiver/amplifier interfaces with an envelope detector module which determines signal amplitude. The sensed amplitude controls a dc-to-dc power supply to a pair of pulse generators. The generated pulse amplitudes are therefore modulated by the envelope detector's response to signal input. This feature proportions return pulse amplitudes to input signal strength. Pulse position or timing commands and mean amplitudes are set by digital interface controls. Delay after trigger for pulse generation is available from 0 to 500 microseconds in 16 microsecond increments.

The receiver/amplifier gain setting has a calibration adjustment available on the front panel of the simulator. This calibration is referenced to an internal voltage source and validation of the setting is made by the level displayed on the front panel readout. Relative input amplitudes, determined by the envelope peak detector, can also be displayed for determining ultrasonic instrument/transducer system performance.

4.4 Digital Circuit Functions

Digital control, schematically presented in Figures 4-8, 4-9 and 4-10, centers around a system featuring 8K bytes of EPROM, 1K bytes of user RAM and 256 bytes of scratch memory. Input-output features include both serial and parallel interfaces with a programmable BAUD rate. User interaction with the simulator is through a 16 element keypad with 28 characters/functions. The front panel contains a 32 character alphanumeric display for information readout. The capability to simulate up to 50 ultrasonic standard features and to perform 40 diagnostic or test functions is available in programmable form. Manual override capabilities allow for direct user commands to perform nonprogrammed functions.

4.5 Transducer Design

The transducers shown in Figure 4-11 are part of the ultrasonic simulator total system. They are designed for two applications; longitudinal and 45 degree

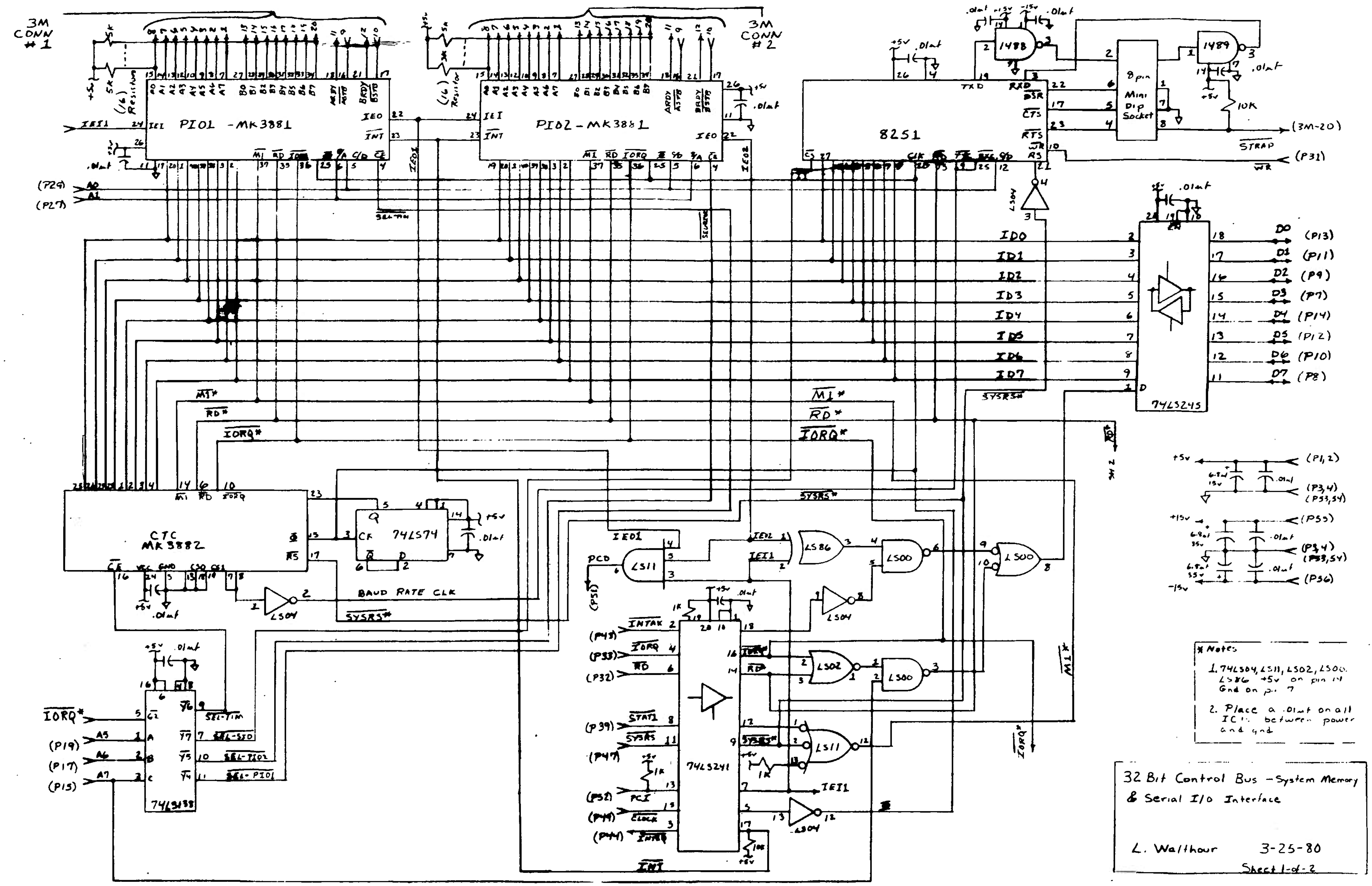


Figure 4-8. Digital Control Bus - System Memory and Serial Input/Output Interface Design (sheet 1 of 2).

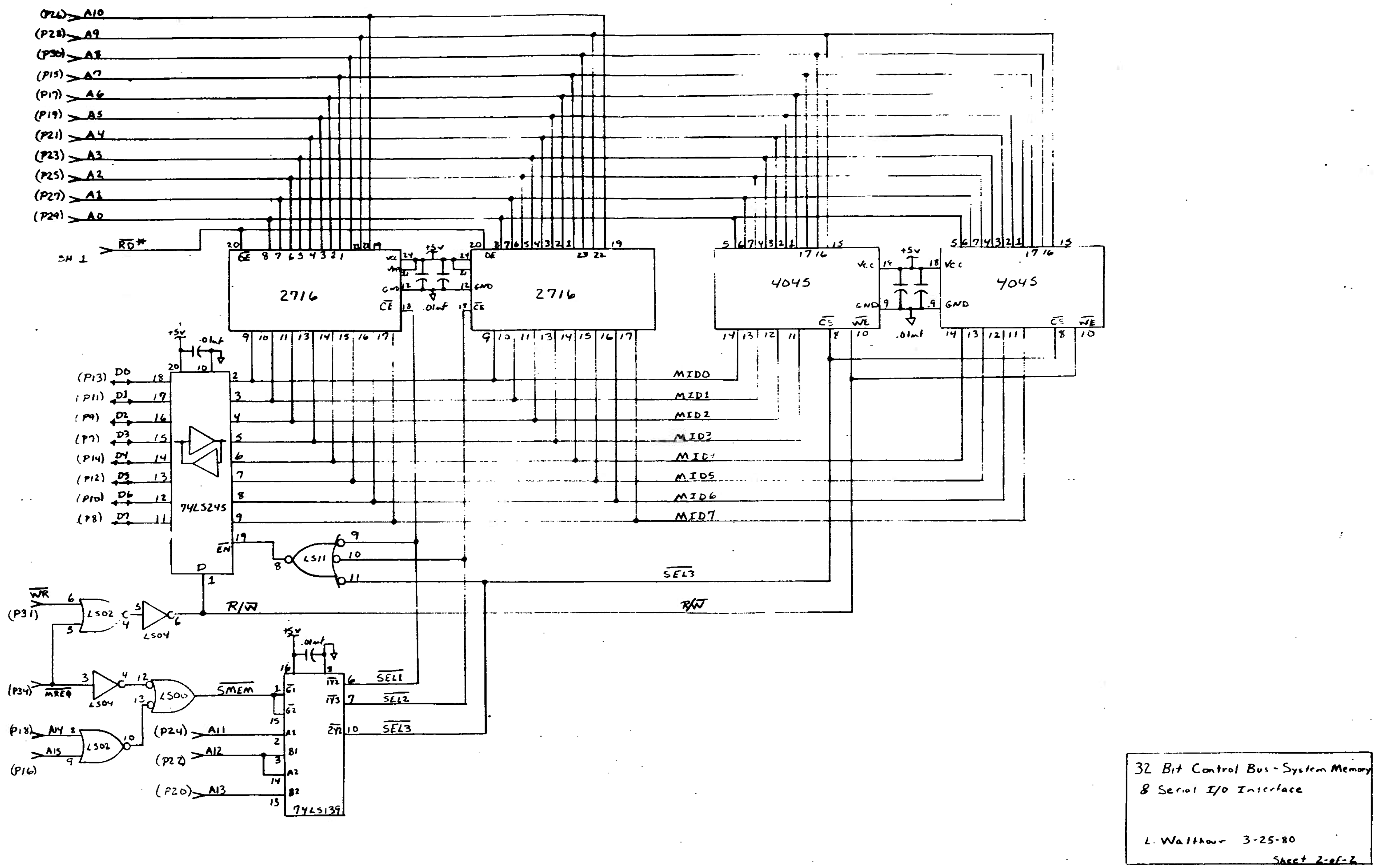


Figure 4-9. Digital Control Bus – System Memory and Serial Input/Output Interface Design (sheet 2 of 2).

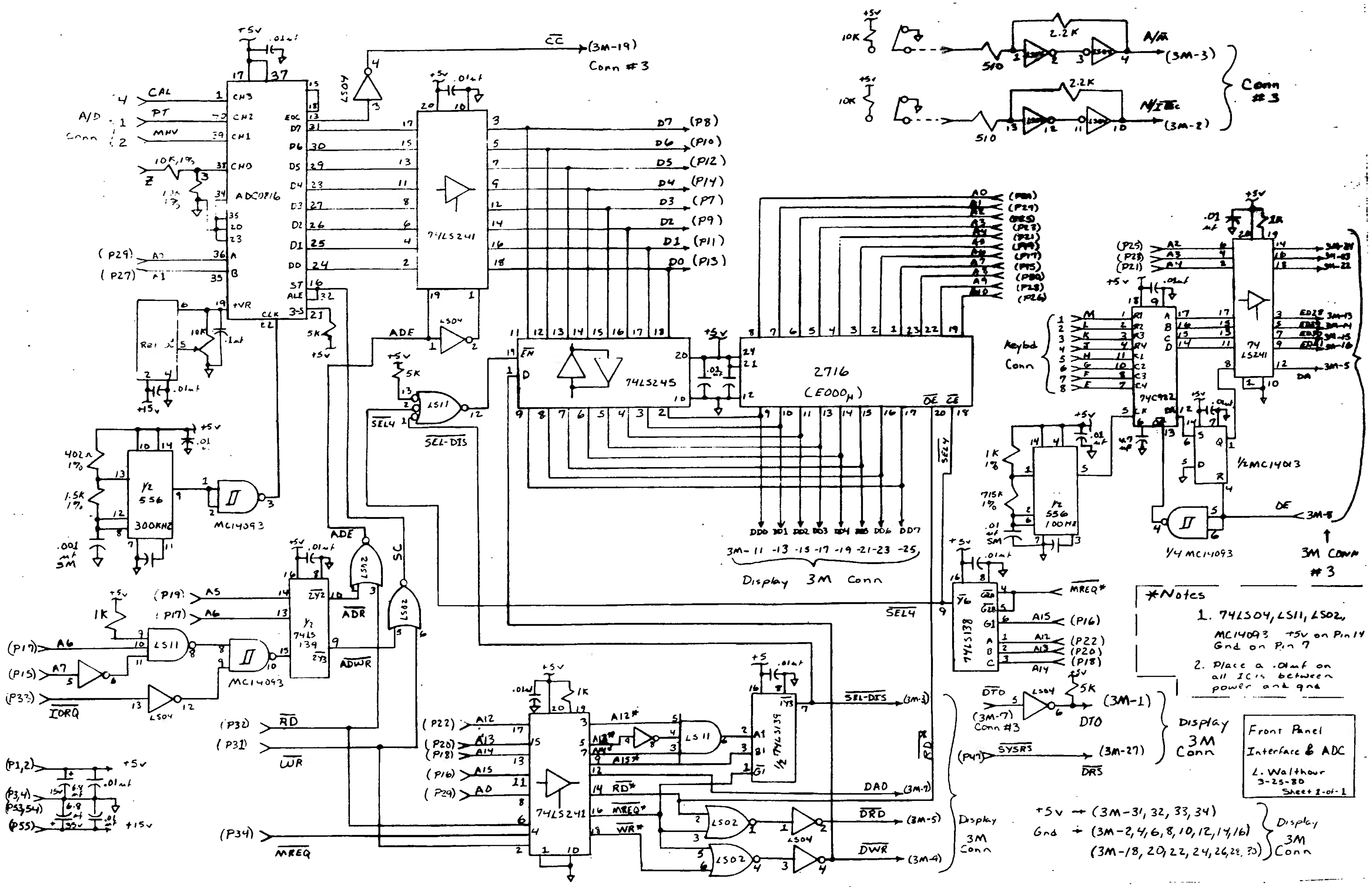


Figure 4-10. Front Panel Control Interface Circuit Design

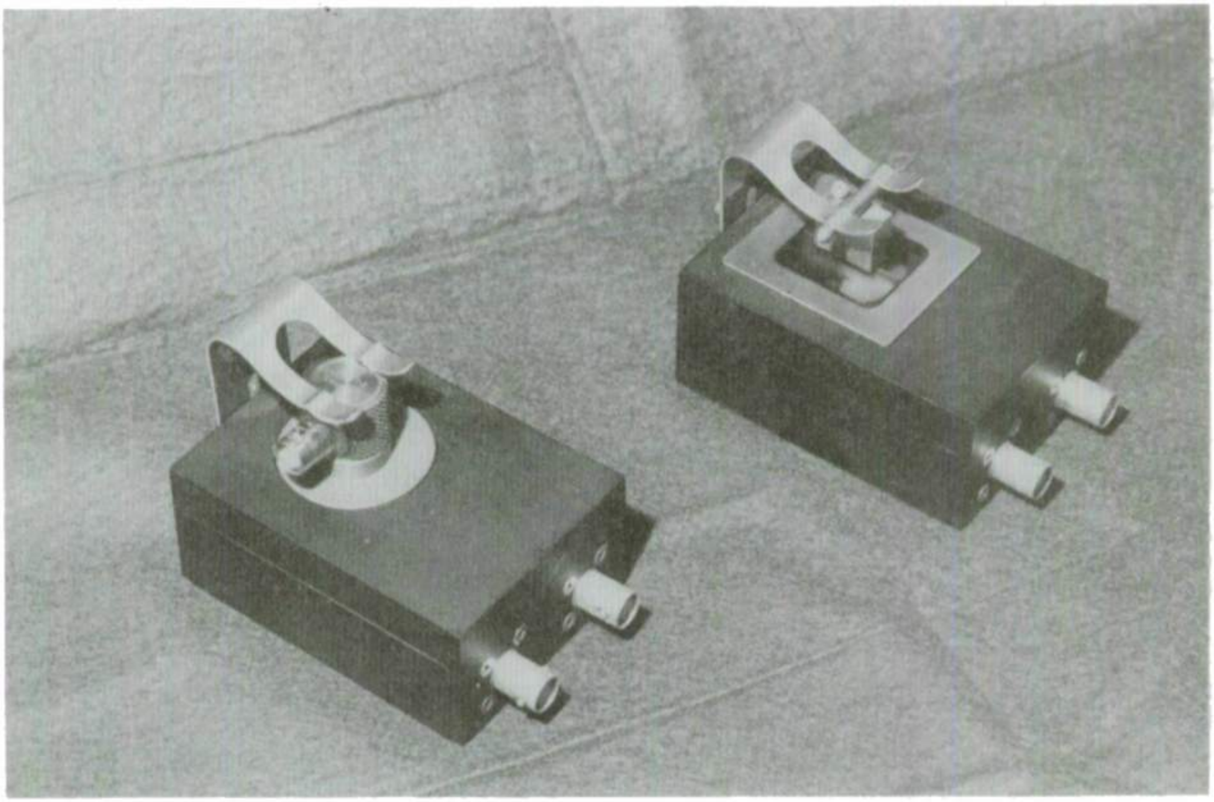


Figure 4-11. Transducers, 0 Degree and 45 Degree, Dedicated to 5 MHz Face-to-Face Operation.

shear wave operation at 5 MHz. (Additional transducers will be required for other frequencies and shear wave angles.) Each transducer contains a 2 cm diameter split element of lead metaniobate. The split element allows for transponder response which triggers and supplies a return pulse without interference from ring-down on the received signal, i.e., one element half is a receiver/transmitter and one half is a transmitter only. The inherent damping of the lead metaniobate material also suppresses ringing and allows for a somewhat unbiased response to electrical pulse excitation.

The electrical impedance characteristics of each transducer (split disk) pair are presented in Figures 4-12 and 4-13. The impedance loci are plotted on Cartesian coordinates with the X-axis values indicating the resistive impedance component. Acoustic loading for the longitudinal wave transducer was only the aluminum oxide wear face, terminated into air. A lucite wedge, terminated into air constituted loading for the shear wave transducer. Both transducers exhibited resonance at slightly above the design value under the continuous wave drive imposed on them by an impedance bridge. Their pulsed ringdown behavior indicated lower frequencies, however. The reflected waveforms for each transducer driven by pulse excitation, are presented in Figures 4-14 and 4-15. One further characterization, loop sensitivity, was made on the longitudinal wave transducer. The response for a return echo involving a 10 cm path length and 100 volts peak excitation was 100 millivolts peak, i.e., 1/1000 voltage ratio.

Both transducers are housed in fixtures to provide mounting for the simulator transducers and hold-downs for the transducers under test. The matter of coupling has been examined for this configuration, with water, oil and silicone grease tested for couplant desirability. Silicone grease (General Electric MIL-S-8660) as a couplant, with applied pressures ranging from 1×10^3 to 5×10^4 Newtons per square meter, provide uniform response within one decibel over the entire load range. Typically, a 1 mm deflection or preload on a small (1 cm^2) transducer will provide more than adequate coupling pressure. It is intended that the operator will monitor the coupling level via the simulator readout in the normal setup process.

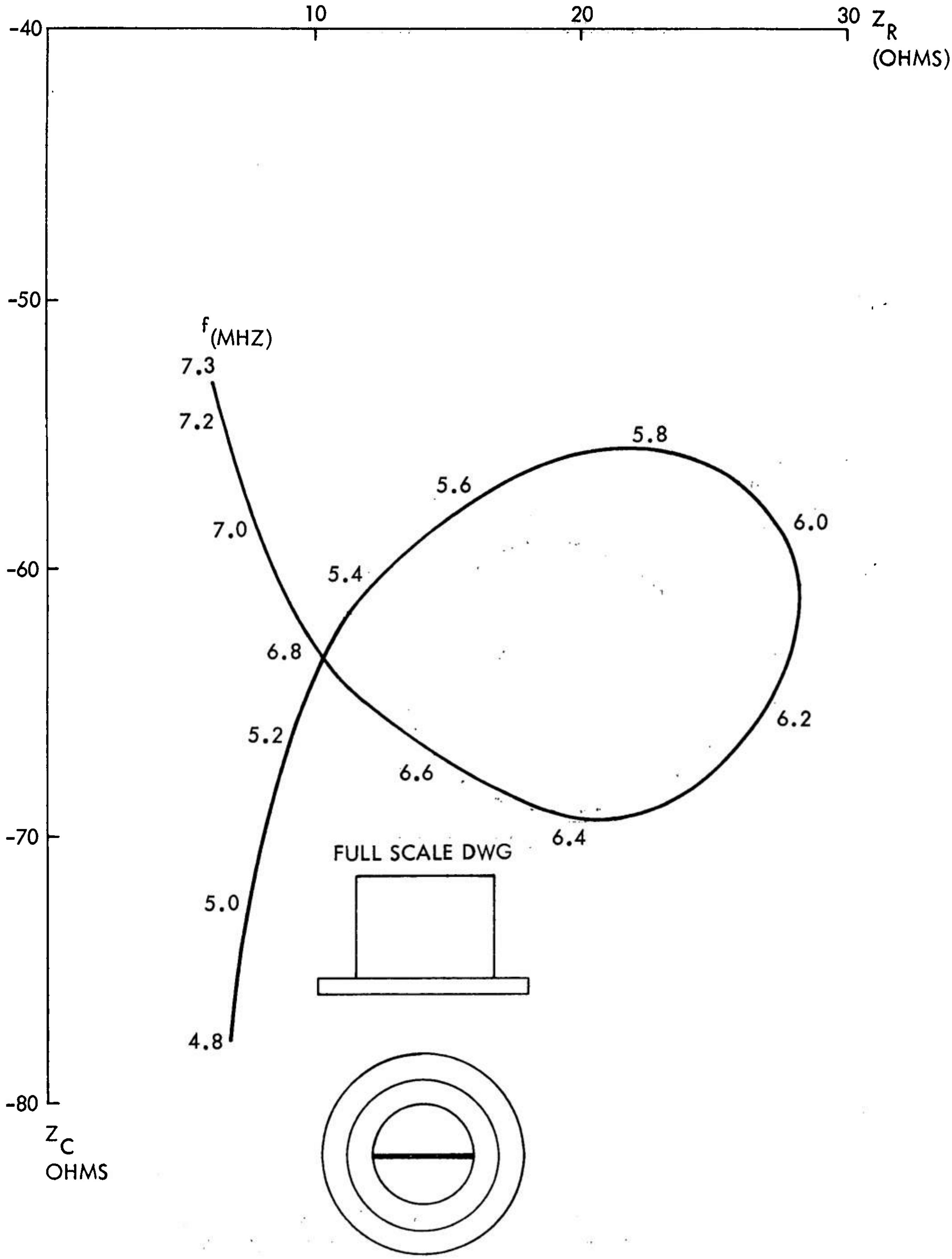


Figure 4-12. Impedance Locus for the Left Half of the 0 Degree Split Element Transducer (sheet 1 of 2).

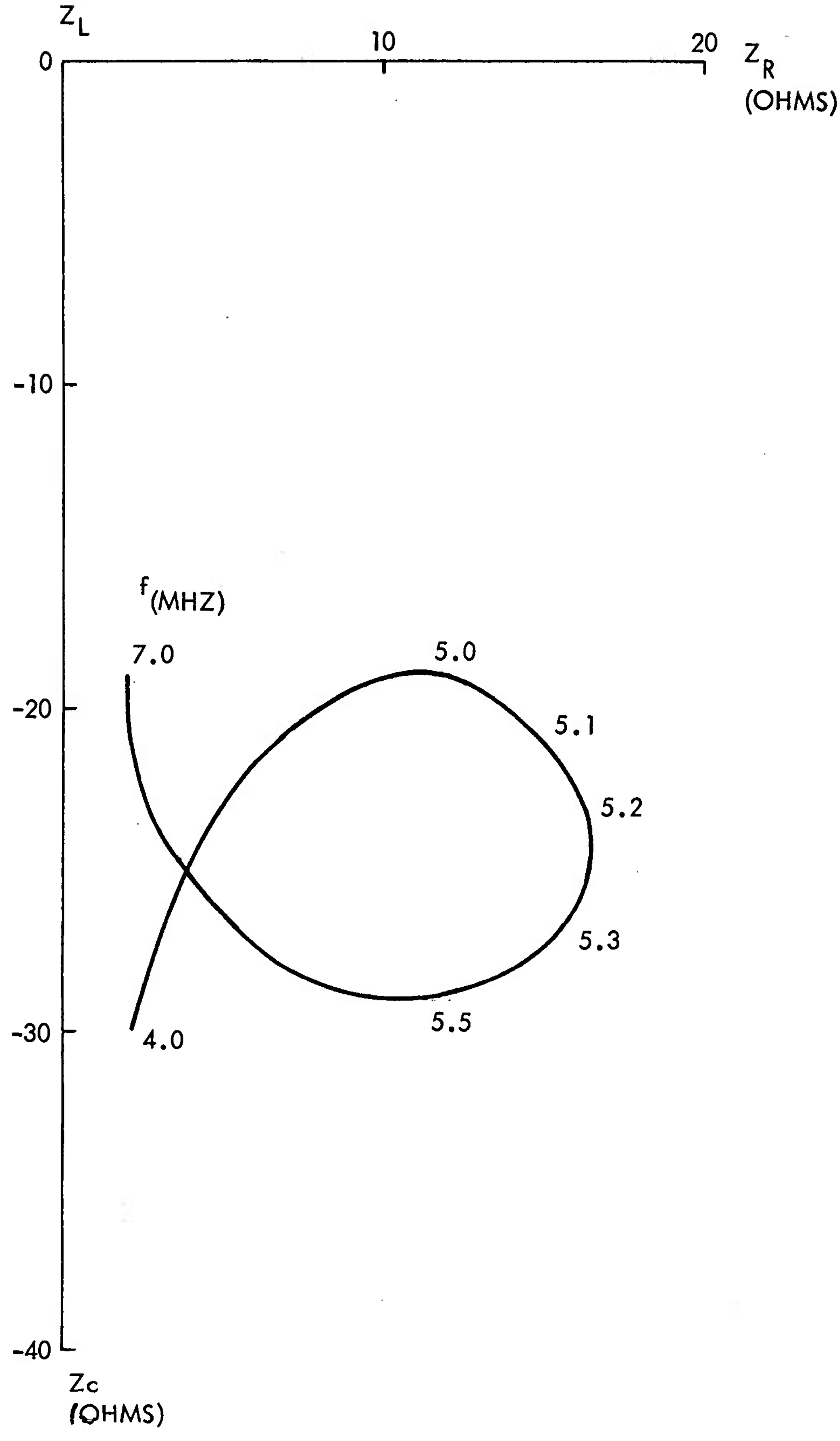
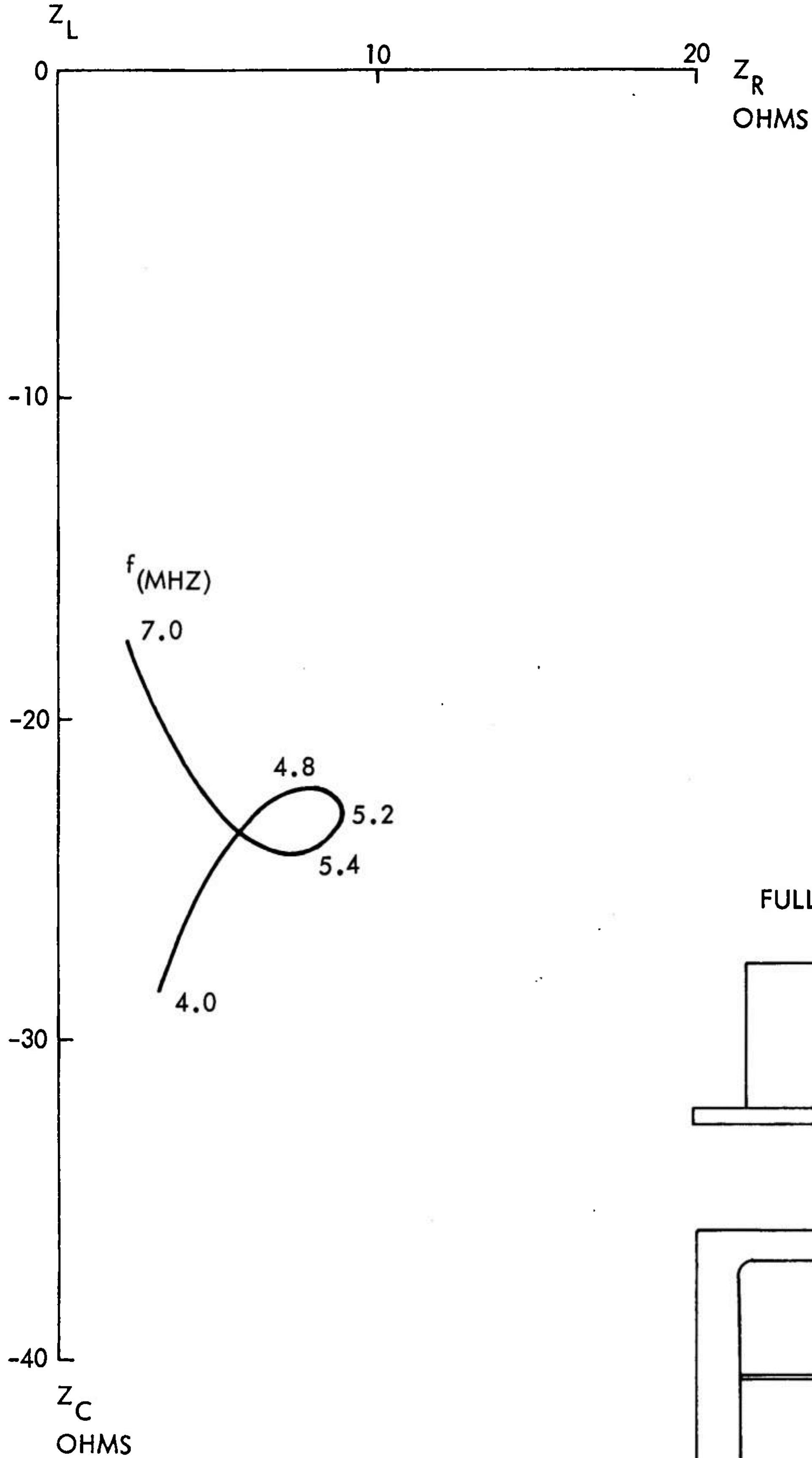


Figure 4-12. Impedance Locus for the Right Half of the 0 Degree Split Element Transducer (sheet 2 of 2).



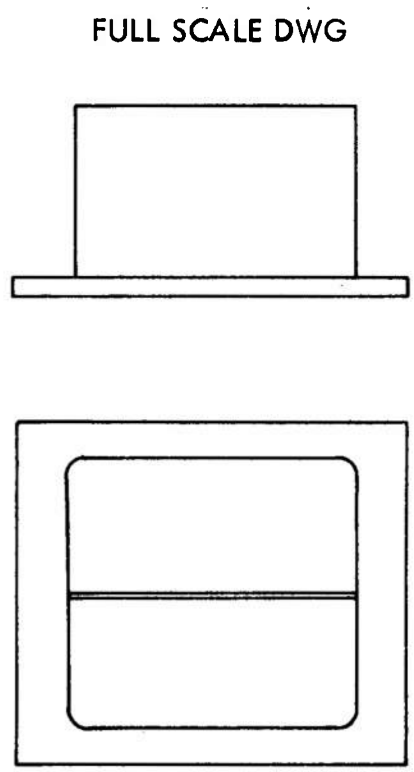


Figure 4-13. Impedance Locus for the Left Half of the 45 Degree Split Element Transducer (sheet 1 of 2).

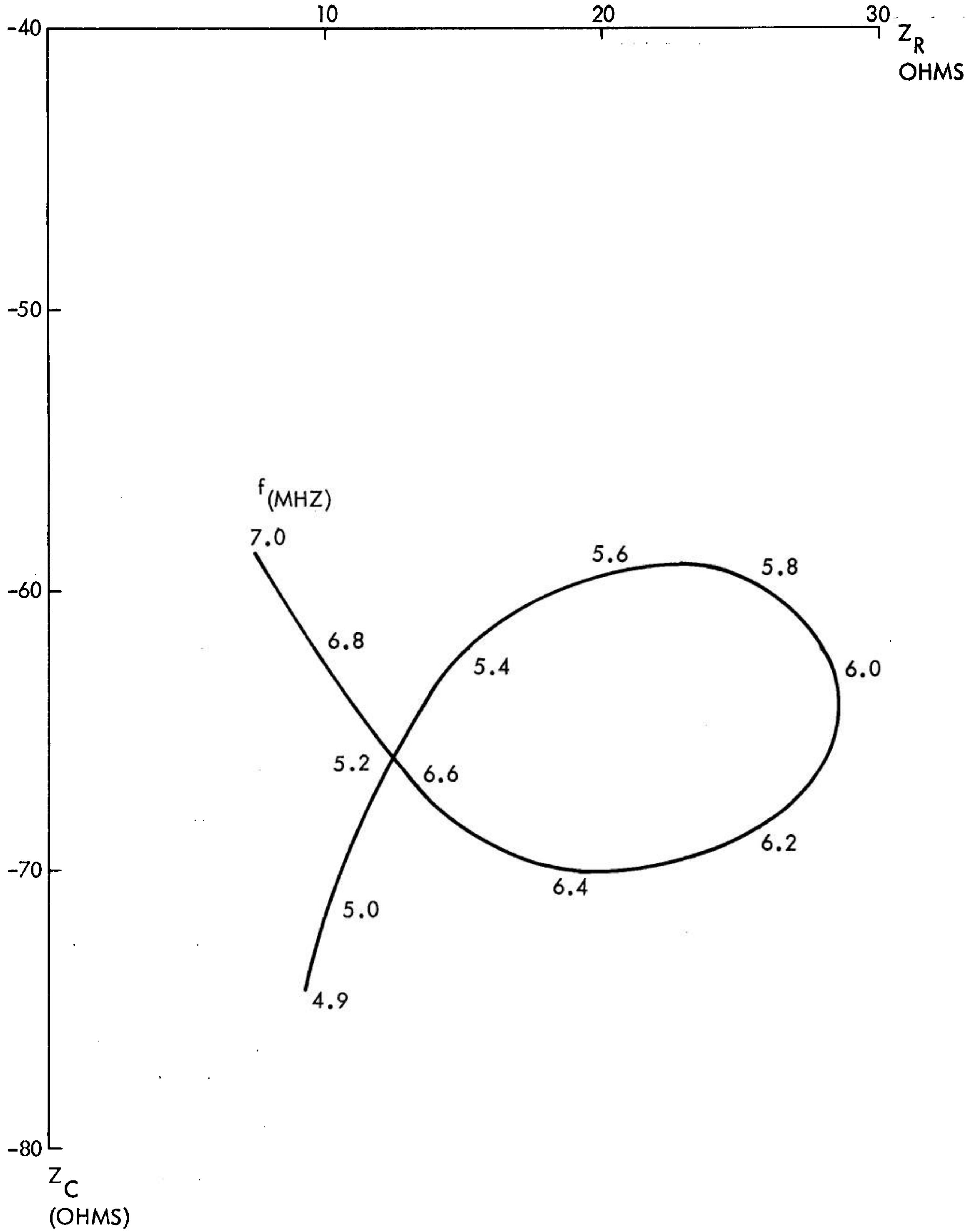


Figure 4-13. Impedance Locus for the Right Half of the 45 Degree Split Element Transducer (sheet 2 of 2).

R. F. WAVEFORM ANALYSIS

SEARCH UNIT

MODEL NO. SWS 25   SERIAL NO. 307

STYLE dual   TEST ANGLE 0°

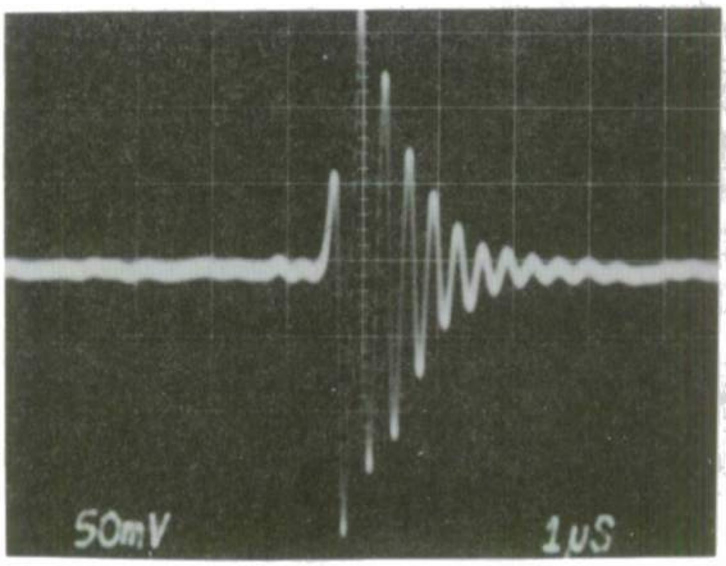
SIZE 2 cm   FREQUENCY 3.5 MHz

INSTRUMENTATION: ULTRASONIC ANALYZER MODEL 5052UA

ATTEN. 22 dB   DAMPING 50   PULSE ENERGY 1/140 V

MODE Thru   REFLECTOR 4" Steel block back surface

MEASURED: FREQUENCY 3.25 MHz   DAMPING FACTOR 4.5



REVIEWED AND ACCEPTED ☒   REJECTED ☐

BY: J T McElroy   DATE: 13 Dec 79

Figure 4-14. R. F. Waveform Analysis for the 0 Degree Transducer, Dual Element Excitation.

R. F. WAVEFORM ANALYSIS

SEARCH UNIT

MODEL NO. SUS 94 SERIAL NO. 302

STYLE dual TEST ANGLE 45°

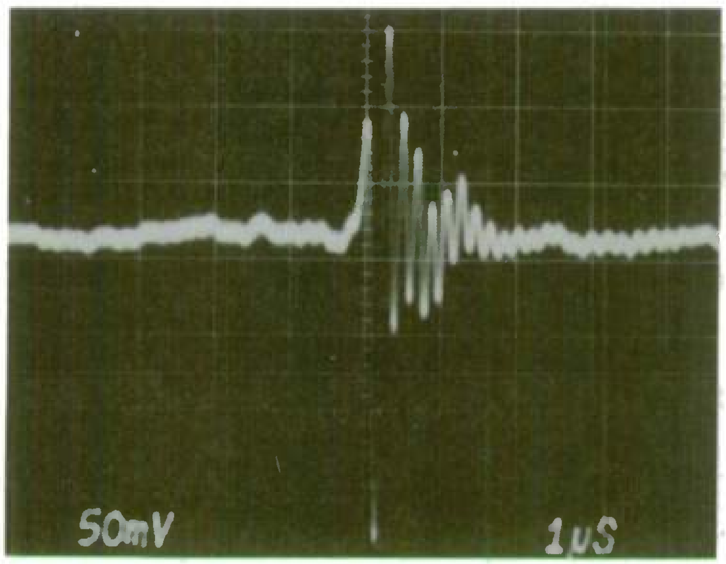
SIZE 2 cm FREQUENCY 5 MHz

INSTRUMENTATION: ULTRASONIC ANALYZER MODEL 5052UA

ATTEN. 6 dB DAMPING 50 Ω PULSE ENERGY 2/100V

MODE Thru REFLECTOR Corner reflection 2" steel Block

MEASURED: FREQUENCY 4.7 MHz DAMPING FACTOR 4



REVIEWED AND ACCEPTED ☐ REJECTED ☐

BY: ____________________ DATE: ____________________

Figure 4-15. R. F. Waveform Analysis for the 45 Degree Transducer, Dual Element Excitation.

REFERENCES

(1) Birnbaum, G. and Eitzen, D. G., "An Appraisal of Current and Future Needs in Ultrasonic NDE Standards", National Bureau of Standards Report No. NBSIR79-1907, Washington, D.C. 20234, October 1979.

(2) Lewis, W. H., Sproat, W. H., Dodd, B. D., and Hamilton, J.M., "Reliability of Nondestructive Inspections", U. S. Air Force Logistics Command Report No. SA-ALC/MME 76-6-38-1, December 1978.

(3) Cosgrove, D. G., "Determining the Linearity of an Ultrasonic Unit", Materials Evaluation, Volume 25, No. 11, November 1967.

(4) Chaskelis, H. H., "A Materials and Defect Simulator for Calibrating Ultrasonic Equipment Used in Nondestructive Testing or Inspection", U. S. Naval Research Laboratory, Washington, D. C., December 1969.

(5) Lewis, W. H., Sproat, W. M., Pless, W. H., "Government/Industry Workshop on the Reliability of Nondestructive Inspections", U. S. Air Force Logistics Command Report No. SA-ALC/MME 76-6-38-2, August, 1978.

APPENDIX

ULTRASONIC STANDARD SIMULATOR OPERATION

A.1 Simulator Description

The ultrasonic standard simulator is designed to assist the user in three functions:

1. Equipment checkout and calibration,
2. Set-up on reference standards, and
3. Diagnosis of malfunction.

The first two functions are normally conducted prior to flaw detection and measurement. Checkout and calibration involves the determination of equipment operating performance and the establishment of initial control settings. The set-up on reference standards is the final equipment control adjustment operation before flaw detection and measurement. If the equipment does not appear to operate properly, the diagnosis is performed to aid in identifying component malfunction.

This simulator is an electronic device which operates on 117 volt AC line power. Simulation of ultrasonic response is provided by an internal pulser with controllable features of pulse height, width and position.

In the first part of the equipment checkout and calibration, the instrument is directly connected to the simulator which replaces the transducer, as shown in the block diagram in Figure 4-1. The second part of the calibration uses the transducer in the system as shown in Figure 4-2. Direct connection of the instrument to the simulator is available through either Microdot, BNC or UHF connectors provided, operation with the transducer in the system is performed with a face-to-face configuration on a transducer which is part of the simulator system.

Controls used in operating the simulator, as pictorially shown in Figure A-1, are the:

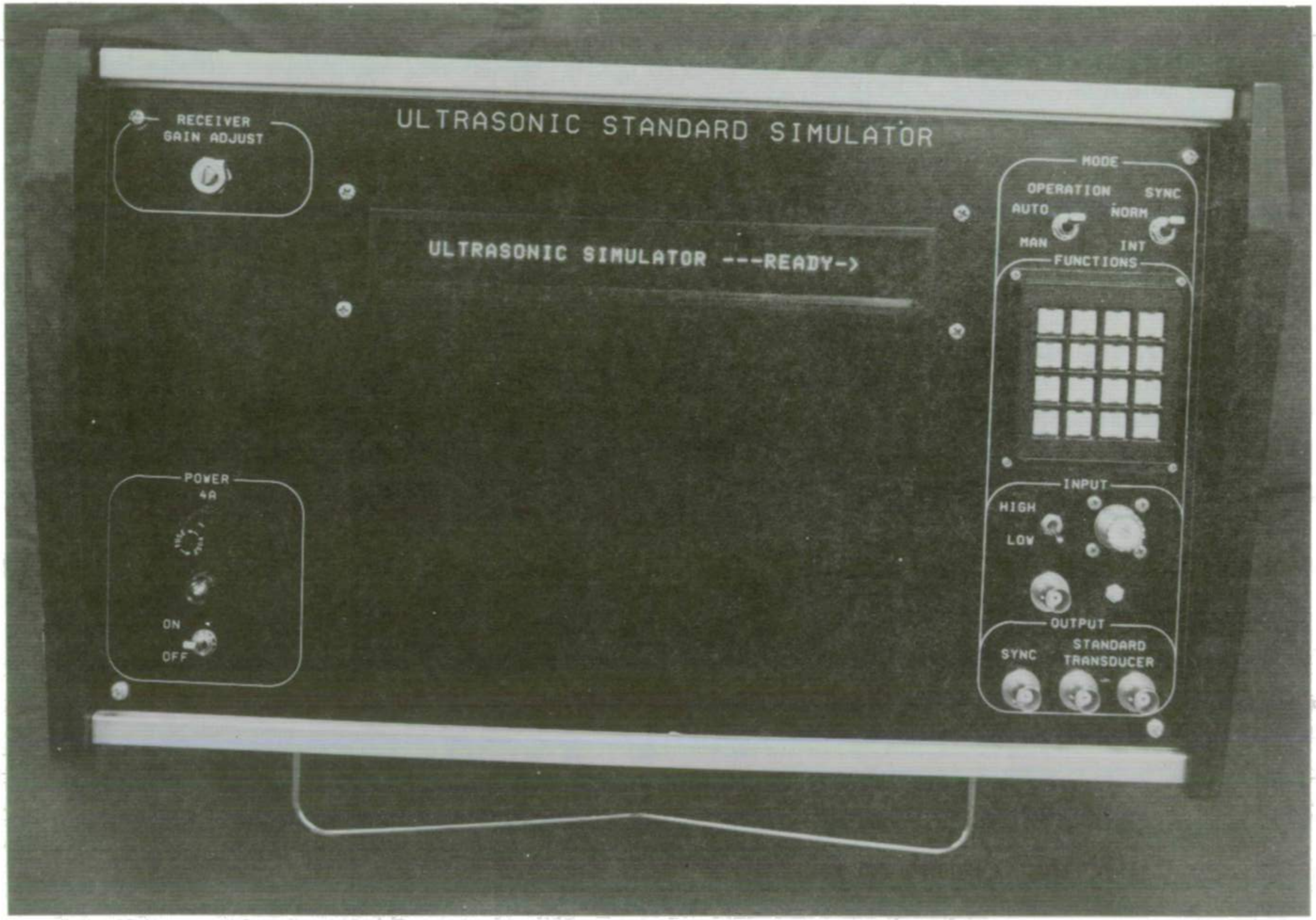


Figure A-1. Ultrasonic Standard Simulator Front Panel Controls, Display and Connections.

I. Power Switch

II. Mode Switch (Automatic/Manual)

III. Mode Switch (Synchronization, Normal/Internal)

IV. 16 Key Pad with 28 Symbols as described in Figure A-2

V. Input Switch (High/Low)

VI. Receiver Gain Adjust (Locking Potentiometer)

The use of these controls is described in the following sections:

A.1.1 Test Mode Description

The mode of operation for the simulator is selectable from the front panel (MODE SWITCH (AUTOMATIC/MANUAL)). The automatic mode provides the operator with a preprogrammed set of conditions for performance of the following series of tests. Test Series: 1.X - Positive Ramp; 2.X - Constant Amplitude and Equal Spacing; 3.X - Negative Ramp and 5.X - Transducer and Pulser/Receiver Check.

The manual mode currently enables the operator to select one of the following functions: 1 - Pulser/Receiver; 2 - Transducer and 3 - Amplitude.

A.1.1.1 Automatic Test Mode Numbers 1.0, 1.1 and 1.2 produce a five pulse increasing ramp function. The amplitude of the third pulse is equivalent to the response from a number 5 flat bottomed hole in aluminum at 4.4 cm distance from a 1.9 cm diameter, longitudinal wave transducer. The total ramp function time is 160 microseconds and individual pulses are 1.0 microseconds duration. Test mode numbers 1.1 and 1.2 are equivalent except the pulse widths are 2.0 and 4.0 microseconds respectively. Typical instrument response is shown in Figure A-3.

A.1.1.2 Automatic Test Mode Numbers 2.0 and 2.1 produce a five pulse, constant amplitude function with a 60 microsecond span from first to last pulse as shown in Figure A-4. Pulse widths are 2 microseconds for test number 2.0 and 4 microseconds for test number 2.1. The sequence for displays and key press operations are the same as in A.2.1.1.1.

1 TST	2 FRQ	3 DLY	4 WID
5 MP	6 POS	7 STR	8 STP
9 ENT	0 CLR	. CON	F C
CAL	←	→	NUM

The 28 symbols are either numeric, word abbreviations or pulse position related. The non-numeric symbols and their parameter values are the following:

TST	=	TEST
FRQ	=	FREQUENCY (1.0, 2.25, 5 or 10 MHz)
DLY	=	PULSE DELAY (10., 20., 30., 40., 50. MICROSECONDS)
WID	=	PULSE WIDTH (.25, .5, 1., 2., 4. MICROSECONDS)
AMP	=	PULSE AMPLITUDE (0 - PR, 1 - 2V, 2 - 4V, 3 - 6V, 4 - 8V, 5 - 10V)
POS	=	PULSE POSITION
STR	=	START
STP	=	STOP
ENT	=	ENTER
CLR	=	CLEAR
CON	=	CONTINUE
F	=	FINE PULSE POSITION
C	=	COARSE PULSE POSITION
CAL	=	CALIBRATE
←	=	PULSE INCREMENT LEFT
→	=	PULSE INCREMENT RIGHT
NUM	=	UPPER CASE KEY ENTRY

Figure A-2. Keypad Symbols for Ultrasonic Standard Simulator Function Controls.

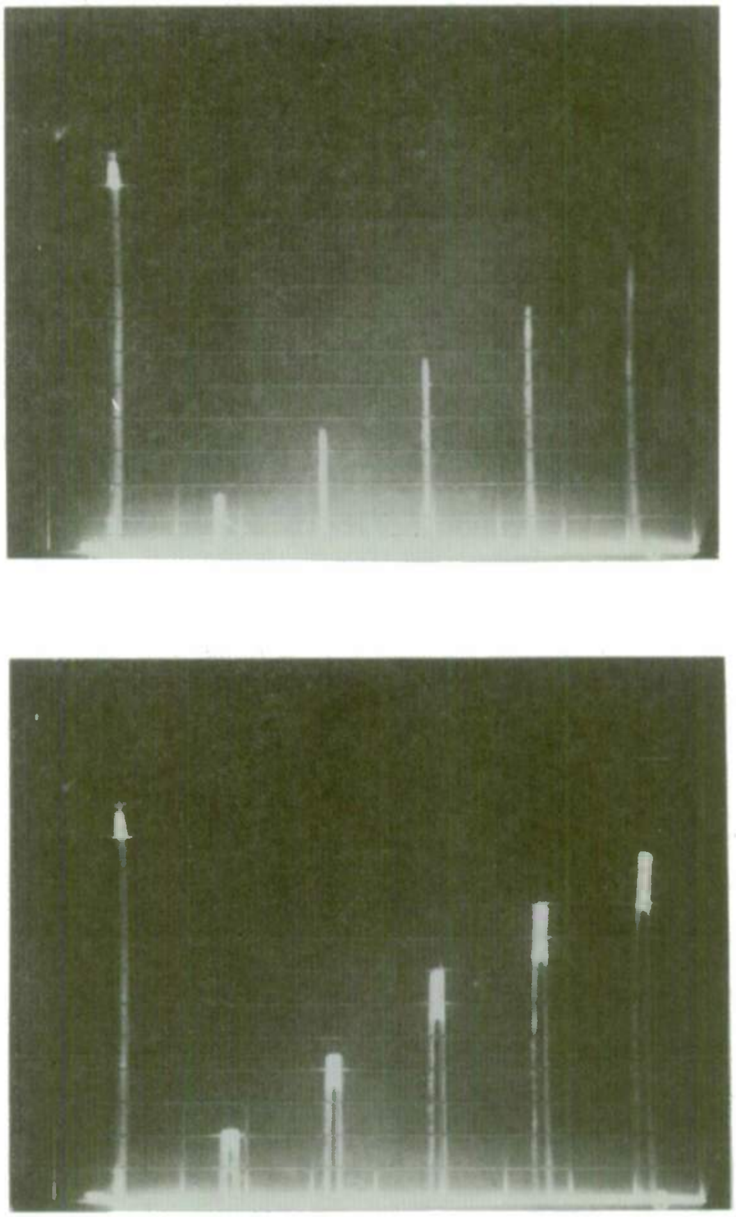


Figure A-3. Automatic Test Mode (Direct Connect) 1.0 and 1.2 Responses by an Ultrasonic Instrument. Pulse Widths are 1 and 4 Microseconds.

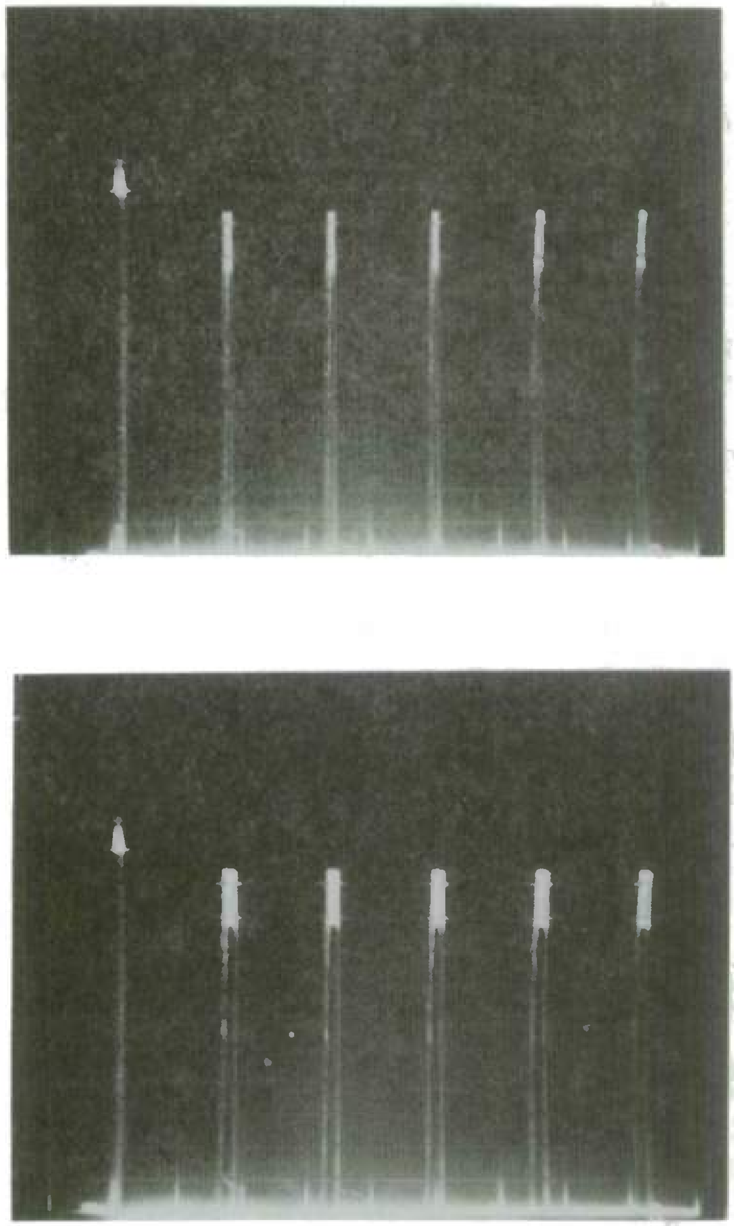


Figure A-4. Automatic Test Mode (Direct Connect) 2.0 and 2.1 Responses by an Ultrasonic Instrument. Pulse Widths are 2 and 4 Microseconds.

A.1.1.3 Automatic Test Mode Numbers 3.0, 3.1 and 3.2 produce a declining amplitude ramp function with five pulses as shown in Figure A-5. The operation is identical with descriptions in A.1.1.1 and A.2.2.1 except for the ramp direction.

A.1.1.4 Automatic Test Mode Numbers 5.0, 5.1 and 5.2 produce a three pulse sequence which simulates the response of a 1.9 cm inch diameter longitudinal wave transducer to a number 5 flat bottomed hole in aluminum at 4.4 cm inch distance. Both front and back surface echoes are simulated along with the flat bottomed hole. Instrument responses to test modes 5.0 and 5.1 are depicted in Figure A-6.

A.1.1.5 Manual Test Mode Number 1 - Pulser/Receiver

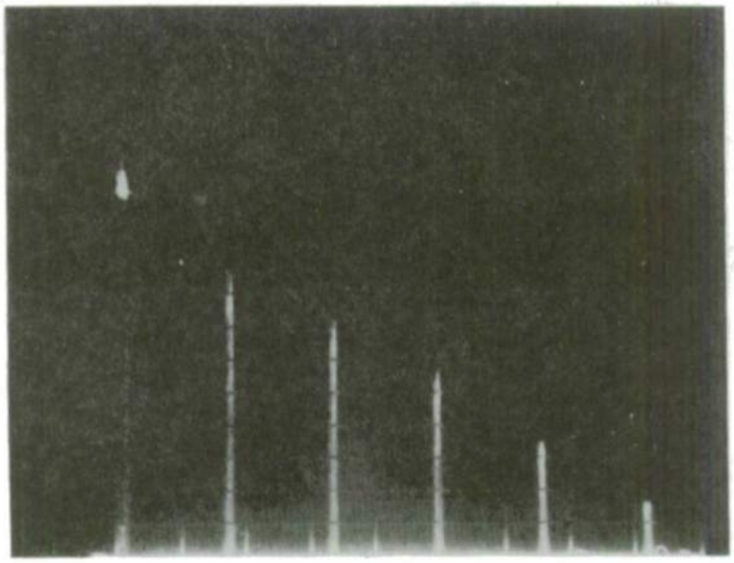
This test mode is the same as Automatic Test Mode Number 1.X, except a variable pulse width is selectable.

A.1.1.6 Manual Test Mode Number 2 - Transducer

Manual Test Mode 2 is similar to Automatic Test Mode 5.X. However this mode allows the operator the freedom to provide appropriate values to the pulse parameters - frequency, delay and amplitude. Also the operator is able to select the time base location of the mid (flat bottomed hole) signal through the use of the direction arrow (← →) keys on the key pad. The increment of movement of the signal is controlled by the (F/C) Fine/Coarse key on the key pad.

A.1.1.7 Manual Test Mode Number 3 - Amplitude

Test Mode 3 provides a voltage readout (display) of the internal pulser power supply; output of the two internal pulsers; the input amplitude of an external pulser and the amplitude of the internal oscillator.



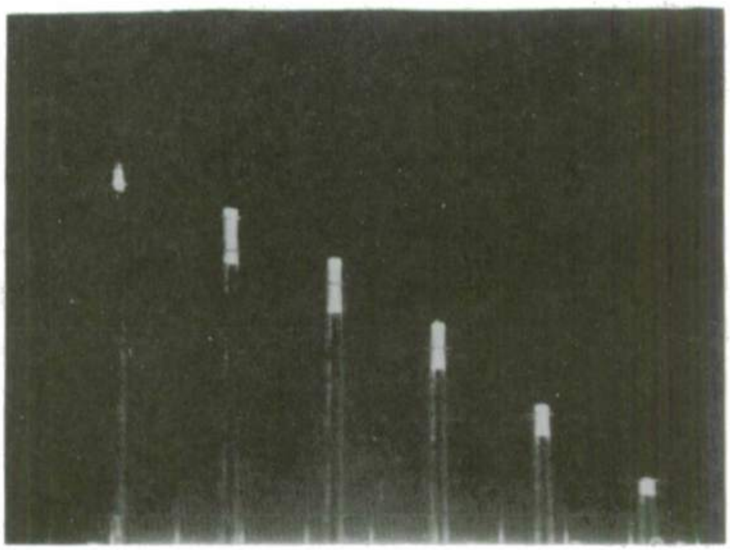


Figure A-5. Automatic Test Mode (Direct Connect) 3.0 and 3.2 Responses by an Ultrasonic Instrument. Functions are the Same as 1.0 and 1.2 Except for Slope.

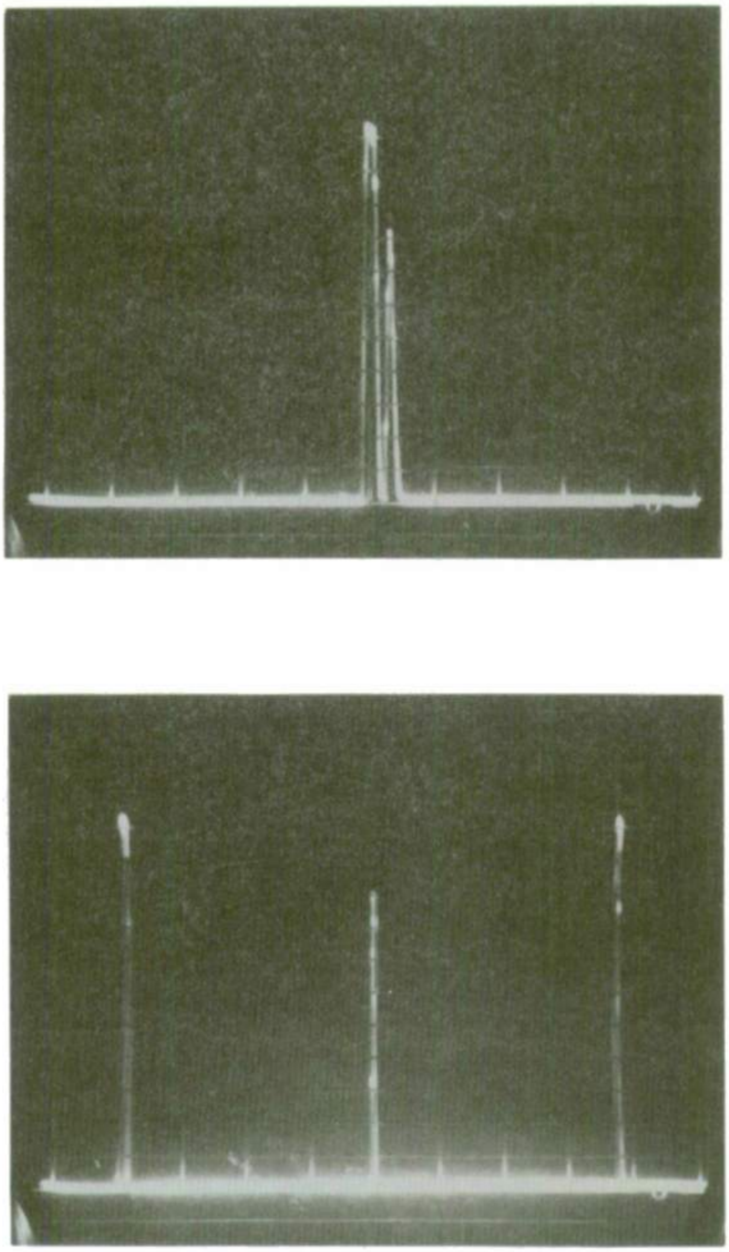


Figure A-6. Automatic Test Mode (Face-to-Face) 5.0 and 5.1 Responses by an Ultrasonic Instrument. The Two Adjacent Pulses Simulate Near Surface Resolution. The Second Photo Shows Simulation of a Mid-Position Reflector in the Sound Path.

A.2 <u>Checkout and Calibration, Direct Connection to the Instrument</u>

The ultrasonic instrument is connected directly to the Ultrasonic Standard Simulator with a coaxial cable.

Both automatic and manual modes of operation are available for directly connected checkout and calibration.

A.2.1 Linearity Checks

The following sequences are to be used in order to determine the amplitude and sweep linearity of the ultrasonic instrument.

A.2.1.1 Automatic Mode, Test Series 1.X

Front Panel Control Settings:

Mode = Auto

Input = See Table A-I

Sync = Norm

A.2.1.1.1 Key/Display Sequence

Note: Items in quotation marks " " denotes displayed message.

A right arrow (→) at end of display denotes waiting for a continue (CON) command.

Turn the power switch to the ON position and wait until display shows:

"Ultrasonic Simulator --- Ready"

a. press CON : "Select Test Mode" (Auto)

b. press CON : "Automatic Mode Enter Num"

c. press TST : "Test No."

d. press NUM : " ^" (denotes upper case key values)

e. press 1.0, 1.1 or 1.2 : "1.X ^"

f. press NUM : "1.X "

g. press ENT : "Select HI/LOW Switch Position"

h. Manually select either the High or Low switch on the front panel

i. Press CON : "Switch Position Low" or "Switch Position High"

Instrument Manufacturer	Model	Pulser Voltage (Kv)	Input
Automation Industries	715/10N	0.9 to 1.0	HI
Automation Industries	775/10N	0.9 to 1.0	HI
Automation Industries	UJ	0.35 to 0.50	LO
Automation Industries	M80	0.9 to 1.0	HI
Automation Industries	M90	0.50	HI
Branson	301M	0.16	LO
Branson	303B	0.20	LO
Nortec	131	0.20	LO
Sonic	Mark I	0.20 to 0.30	LO
Tektran	725	1.0	HI

TABLE A-I PULSE INPUT SETTINGS FOR COMMERCIAL INSTRUMENTS

j. Press CON : "Sel One of the Following Funct →"

k. Press CON : "Pulser/Receiver Unit 0-Pos, 1-Neg"

l. Press NUM : "Pulser/Receiver Unit 0-Pos, 1-Neg ^"

m. Press 0 : "0 ^"

n. Press NUM : "0"

o. Press ENT : "Positive Pulser →"

p. Press CON : "Select Freq. (1,2.25,5,10 MHz)"

q. Press FRQ : "Freq = "

r. Press NUM : "Freq = ^"

s. Press 1, 2.25, 5 or 10 : "Freq = X.X ^ "

t. Press NUM : "Freq = X.X "

u. Press ENT : "Freq = X.X MHz"

v. Press STR : "Test No. 1.X Executing"

Note: To Halt Test

* Press STP : "Test Sequence Interrupted"
* Press CON to restart test sequence

A.2.1.1.2 Performance Criteria - Adjust the SWEEP DELAY and RANGE on the ultrasonic instrument to place the main pulse at the left-hand side of the display and the final generated pulse at the right-hand side. Final adjust the ultrasonic instrument GAIN for the largest generated pulse to reach full (100%) screen height.

A.2.1.2 Automatic Mode, Test Series are the same as in A.2.1.1

Note: Observe the pulse train displayed on the instrument. Deviations from linearity exist if the tips of the pulses do not fall along a straight line. Nonlinearity exceeding 5% of either the full horizontal or vertical scale should be treated as a malfunction.

(This test can be performed in either the video or RF mode.)

A.2.1.3 Automatic Mode, Test Series 3.X

The sequence of operations for this Test Series are the same as in A.2.1.1.

A.2.1.4 Manual Test Mode Number 1 - Pulser/Receiver

Front Panel Control Settings:

Mode = Manual

Input = See Table A-1

Sync = Norm

A.2.1.4.1 Key/Display Sequence

This procedure is identical to procedure A.2.1.1.1 up to step b.

Proceed with those steps selecting the Manual Test Mode then:

a. Press CON : "Manual Test Mode - (Press CON) ➔ "

b. Press CON : "Sel One of the Following Funct ➔ "

c. Press CON : "1-P/R, 2-Transducer, 3-Amplitude"

d. Press NUM : " ^"

e. Press 1 : "1 ^"

f. Press NUM : "1"

g. Press ENT : "Manual Test 1 - (Press CON)"

h. Press CON : "Select Function and Value ➔"

i. Press CON : "Function - FRQ, WID"

j. Press FRQ : "Freq = Need to Select a Freq"

k. Press FRQ : "Freq = "

l. Press NUM : "Freq = ^"

m. Press 1, 2.25, 5 or 10 : "Freq = X.X ^"

n. Press NUM : "Freq = X.X"

o. Press ENT : "Freq = X.X MHz"

p. Press STR : "Select HI/LO Switch Position ➔"

q. Manually select either the High or Low switch on the front panel

r. Press CON : "Switch Position Low" or "Switch Position High"

s. Press CON : "Sel One of the Following Funct ➔ "

t. Press CON : "Pulser/Receiver Unit 0-Pos, 1-Neg"

u. Press NUM : "Pulser/Receiver Unit 0-Pos, 1-Neg ∧ "

v. Press 0 or 1 : "0 ∧" or "1 ∧"

w. Press NUM : "0" or "1"

x. Press ENT : "Negative Pulser →" or "Positive Pulser →"

y. Press CON : "Manual Test Executing"

Note: To Halt Test

Press STP : "Test Sequence Interrupted"

Press CON to restart test sequence

A.3 Checkout and Calibration with Transducer

This operation involves the attachment of a standard transducer to the Ultrasonic Standard Simulator with two coaxial connections. In this mode, the total system ultrasonic instrument and search unit, are examined. The Standard Simulator response is proportioned to the input as received by the standard transducer in the face-to-face configuration.

Both automatic and manual modes of operation are available for checkout and calibration with transducer.

Note: Couple the search unit to the standard transducer with silicone grease. Compression is applied to maintain coupling by the adjustable spring clip.

A.3.1 Automatic Mode, Test Series 5.X

Front Panel Control Settings:

Mode = Auto

Input = See Table A-1

Sync = Norm

A.3.1.1 Key/Display Sequence

Turn the power switch to the ON position and wait until display shows: "Ultrasonic Simulator --- Ready"

a. Press CON : "Select Test Mode" (Auto)

b. Press CON : "Automatic Mode Enter Num"

c. Press TST : "Test No."

d. Press NUM : " ∧"

e. Press 5.0, 5.1 or 5.2 : "X.X ∧ "

f. Press NUM : "X.X"

g. Press ENT : "Select Freq (1,2.25,5,10 MHz)"

h. Press FRQ : "Freq = "

i. Press NUM : "Freq = ∧"

j. Press 1, 2.25, 5 or 10 : "Freq = X.X ∧ "

k. Press NUM : "Freq = X.X"

l. Press ENT : "Freq = X.X MHz"

m. Press STR : "Test No. 5.X Executing"

Note: To Halt Test

* Press STP : "Test Sequence Interrupted"
* Press CON to restart test sequence

A.3.2 Manual Test Mode Number 2 - Transducer

Front Panel Control Settings:

Mode = Manual

Input = See Table A-l

Sync = Norm

A.3.2.1 Key/Display Sequence

This procedure is identical to procedure A.3.1.1 up to step b. Proceed with those steps selecting the Manual Test Mode then:

a. Press CON : "Manual Test Mode - (Press CON) → "

b. Press CON : "Sel One of the Following Funct → "

c. Press CON : "1-P/R, 2-Transducer, 3-Amplitude"

d. Press NUM : "1-P/R, 2-Transducer, 3-Amplitude ∧ "

e. Press 2 : "2 ∧"

f. Press NUM : "2"

g. Press ENT : "Manual Test 2 - (Press CON)"

h. Press CON: "Select Function and Value →"

i. Press CON: "Functions - Freq, Dely, Amp(P/S), Pos"

j. Press FRQ : "Freq = X.X MHz"

Note: Frequency can be changed by pressing FRQ again and proceed with key/display sequence k thru o in para. A.2.1.4.1.

k. Press CON: "Functions - Freq, Dely, Amp(P/S), Pos"

l. Press DLY : "Delay = XX. uS"

Note: Delay can be changed by pressing DLY again and selecting a delay value of 10.0, 20.0, 30.0, 40.0 or 50.0.

m. Press CON: "Functions - Freq, Dely, Amp(P/S), Pos"

Note: For no change in amplitude - skip to step v.

n. Press AMP : "Ampl = Proportional Input"

o. Press AMP : "0-Proportional PR, 1 - 2V,2 - 4V,3 - 6V,4 - 8V,5 - 10V →"

p. Press CON: "Ampl = "

Note: Select number for desired amplitude of signal.

q. Press NUM: "Ampl = ^ "

r. Press 0, 1, 2, 3, 4 or 5: "Ampl = X ^ "

s. Press NUM: "Ampl = X "

t. Press ENT : "Ampl = Proportional Input" or "Ampl = X V "

u. Press CON: "Functions - Freq, Dely, Amp(P/S), Pos"

v. Press POS : "Position Control"

Note: Select either Fine or Coarse position control by pressing C (Coarse) or pressing NUM then F (Fine)

w. "Position - Coarse" or "Position - Fine"

Note: To Halt Test

* Press POS : "Functions - Freq, Dely, Amp(P/S), Pos"
* Press STP : "Test Sequence Interrupted"
* Press CON to restart test sequence

A.3.3 Manual Test Mode Number 3 - Amplitude

Front Panel Settings:

Mode = Manual

Input = See Table A-1

Sync = Norm

A.3.3.1 Key/Display Sequence - Calibrate

This procedure is identical to procedure A.3.1.1 up to step b.

Proceed with those steps selecting the Manual Test Mode then:

a. Press CON : "Manual Test Mode - (Press CON) →"

b. Press CON : "Sel One of the Following Funct →"

c. Press CON : "1-P/R, 2-Transducer, 3-Amplitude"

d. Press NUM : "1-P/R, 2-Transducer, 3-Amplitude ^"

e. Press 3 : "3 ^"

f. Press NUM : "3"

g. Press ENT : "Manual Test 3 - (Press CON)"

h. Press CON : "Press (CAL) or (AMP) Key →"

i. Press CAL : "Receiver Calibrate Mode →"

j. Press CON : "Select Freq (1, 2.25, 5, 10 MHz)"

k. Press FRQ : "Freq = "

l. Press NUM : "Freq = ^"

m. Press 1, 2.25, 5 or 10 : "Freq = X.X ^"

n. Press NUM : "Freq = X.X"

o. Press ENT : "Freq = X.X MHz"

p. Press CON : "Ampl = X.XX V"

Note: Amplitude voltage range 2.50v to 3.00v - Adjust Receiver gain if necessary - press CAL after each adjustment to read new amplitude value.

To Halt Test:

* Press STP : "Test Sequence Interrupted"
* Press CON to restart test sequence

A.3.3.2 Key/Display Sequence - Amplitude

Note: Prior to the following procedure - it will be necessary to setup the internal pulsers using Manual Mode #2, procedure paragraph A.3.2, or supply an external trigger through the external pulser input.

This procedure is identical to Procedure A.3.3.1 up to step h.

Proceed with those steps then:

a. Press CON : "Press (CAL) or (AMP) Key"

b. Press AMP : "Amplitude Measurement Mode →"

c. Press CON : "1-HV(P/S), 2-Int-Plsr, 3-Ex-Plsr"

d. Press NUM : "1-HV(P/S), 2-Int-Plsr, 3-Ex-Pls∧"

e. Press 1 : "1 ∧"

f. Press NUM : "1"

g. Press ENT : "Power Supply Output = XXX.XX V"

Note: Voltage measurement of power supply output to internal pulser modules.

h. Press CON : "1-HV(P/S), 2-Int-Plsr, 3-Ex-Plsr"

To Halt Test: Press STP : "Test Sequence Interrupted"

i. Press NUM : "1-HV(P/S), 2-Int-Plsr, 3-Ex-Pls∧ "

j. Press 2 : "2 ∧"

k. Press NUM : "2"

l. Press ENT : "Pulsr 1 = XX.X V Pulsr 2 = XX.X V"

Note: Measures output of the internal pulsers to verify operation.

m. Press CON : "1-HV(P/S), 2-Int-Pulsr, 3-Ex-Pulsr"

To Halt Test: Press STP : "Test Sequence Interrupted"

Note: The following sequences require an external pulser input.

n. Press NUM : "1-HV(P/S), 2-Int-Pulsr, 3-Ex-Puls ∧ "

o. Press 3 : "3 ∧"

p. Press NUM : "3"

q. Press ENT : "Select HI/LO Switch Position → "

r. Place Input High/Low Switch in Low (High) Position

s. Press CON : "Switch Position Low → " or "Switch position High → "

t. Press CON : "External Pulser Input = XXX.XX V"

Note: Measures amplitude of external pulser.

u. Press CON : "1-HV(P/S), 2-Int-Plsr, 3-Ex-Plsr"

To Halt Test: Press STP : "Test Sequence Interrupted"

Note: These measurements do not have to be performed in the order shown. They can be performed independently or in any order desired by using sequence a. thru d. then either of the following sequences e. thru h. or j. thru m. or o. thru u.